CLAS Deep Processes Working Group Summary

24 October 2015
CLAS Collaboration Meeting
Jefferson Lab
Keith Griffioen

Deep Processes Working Group Summary

Oct 2015

- 3 Analysis Notes currently under review
- 8 *ad hoc* reviews in progress or to start soon
- 4 submitted or published papers in 2015
- Several ongoing thesis analyses
- Several ongoing data-mining projects

Jun 2015

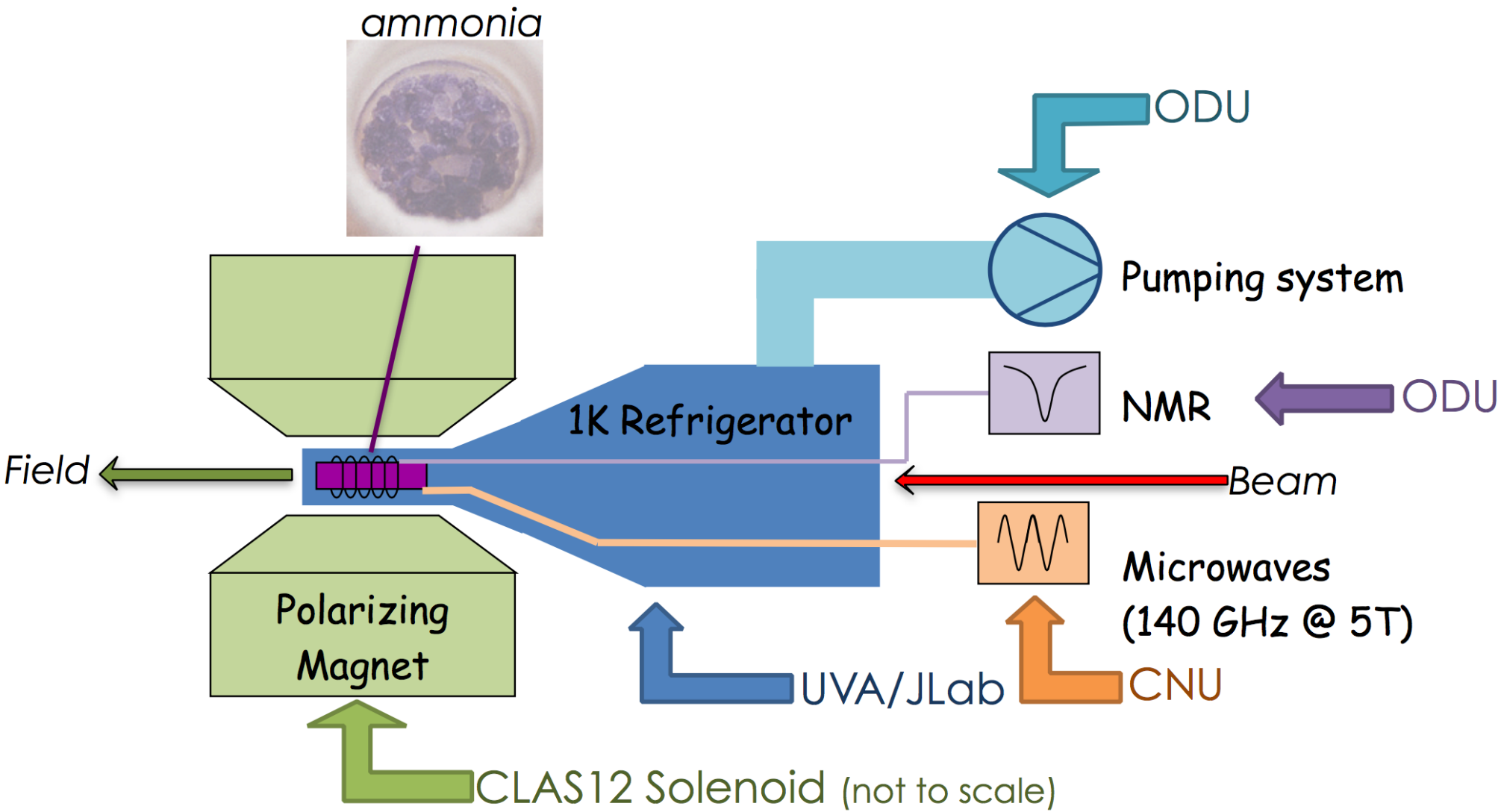
- 7 Analysis Notes currently under review
- 4 *ad hoc* reviews in progress or to start soon
- 4 submitted or published papers in 2015
- Several ongoing thesis analyses
- Several ongoing data-mining projects

Author	Run Group	Title	WGC	ad hoc	Pub
I Albyrak *et al.*	g12	Time-Like Compton Scattering	Begin: 150325 S Niccolai R Paremuzyan M Paolone link		
A Fradi *et al.*	e1-dvcs	Deeply Virtual Production of the ρ^+ Meson on the Proton	Begin: 150316 S Pisano K Giovanetti V Kubarovsky link		
S Koirala S Kuhn *et al.*	eg1-dvcs	Measurement of Single and Double Spin Asymmetries in Semi-Inclusive Deep Inelastic Scattering on Proton and Deuteron	Begin:140929 M Mirazita P Bosted M Contalbrigo link End:151001		
P Bosted *et al.*	eg1b	Spin Asymmetries in Exclusive pi+ and pi- electro-production from the Eg1b experiment	Begin:140909 G Dodge X Zheng FX Girod link End: 150815	Begin:151007 Andrew Puckett Jacques Ball Vitali Baturin	

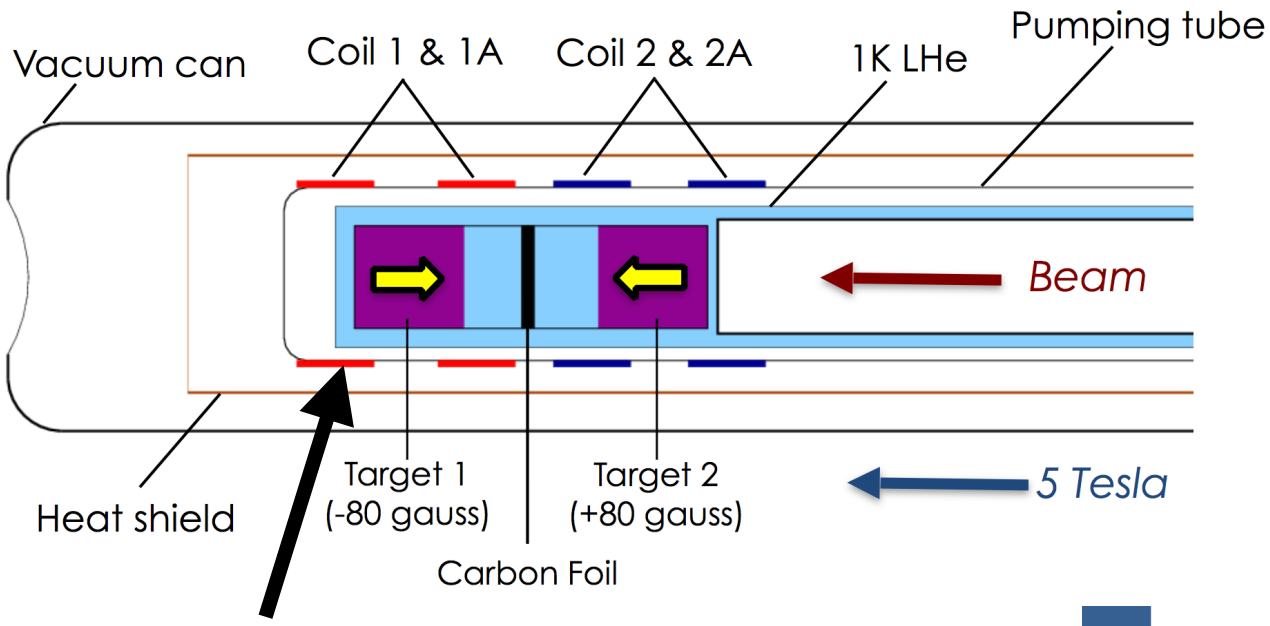
A. Kim *et al.*	e1f	Beam Spin asymmetries of ep -> epη in the deep-inelastic regime	Analysis note unknown	Begin: 140905: Angela Biselli Kijun Park A Celentano	
A. Kim *et al.*	eg1-dvcs	Single and Double Spin Asymmetries for Deeply Virtual Exclusive π^0 Production on Longitudinally Polarized Proton Target with CLAS	Begin: 130912 M. Guidal S. Pisano A. Biselli link End: 140905	Begin: 150615 E Votier A Biselli M Holtrop End: 151016	

I Bedlinskiy V Kubarovsky *et al.*	e1-dvcs	Measurement of cross sections of η electroproduction in e1dvcs experiment with CLAS	Begin:140710 R Dupre H Avagyan A Kim link End:151022		
S Pisano *et al.*	e1f	Di-hadron Beam-Spin Asymmetry in SIDIS electro-production	Begin:140424 A Biselli B Raue S Kuhn link		
P Bosted *et al.*	eg1-dvcs	Spin Asymmetries in exclusive π^+, π^0, and π^- electro-production from the eg1-dvcs experiment	Begin:140120 FX Girod S A Pereira P Stoler link End: 090214	Begin: 150903 FX Girod S Bueltmann Jixie Zhang	

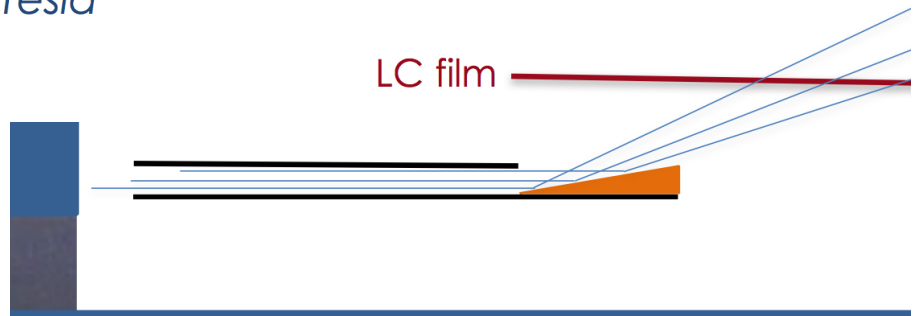
Chris Keith
on the polarized NH_3/ND_3 target



Sebastian Kuhn: *We can also use internal, superconducting coils to adjust the polarizing field for **two target samples**, and take data on **both polarizations simultaneously**.*

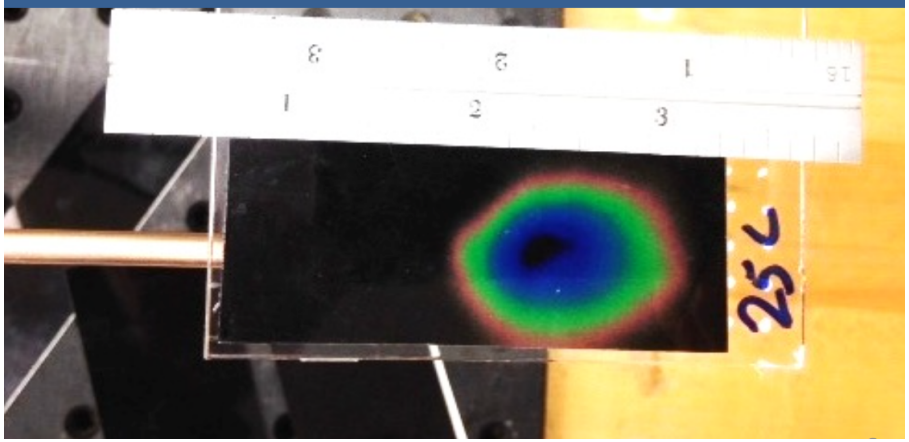


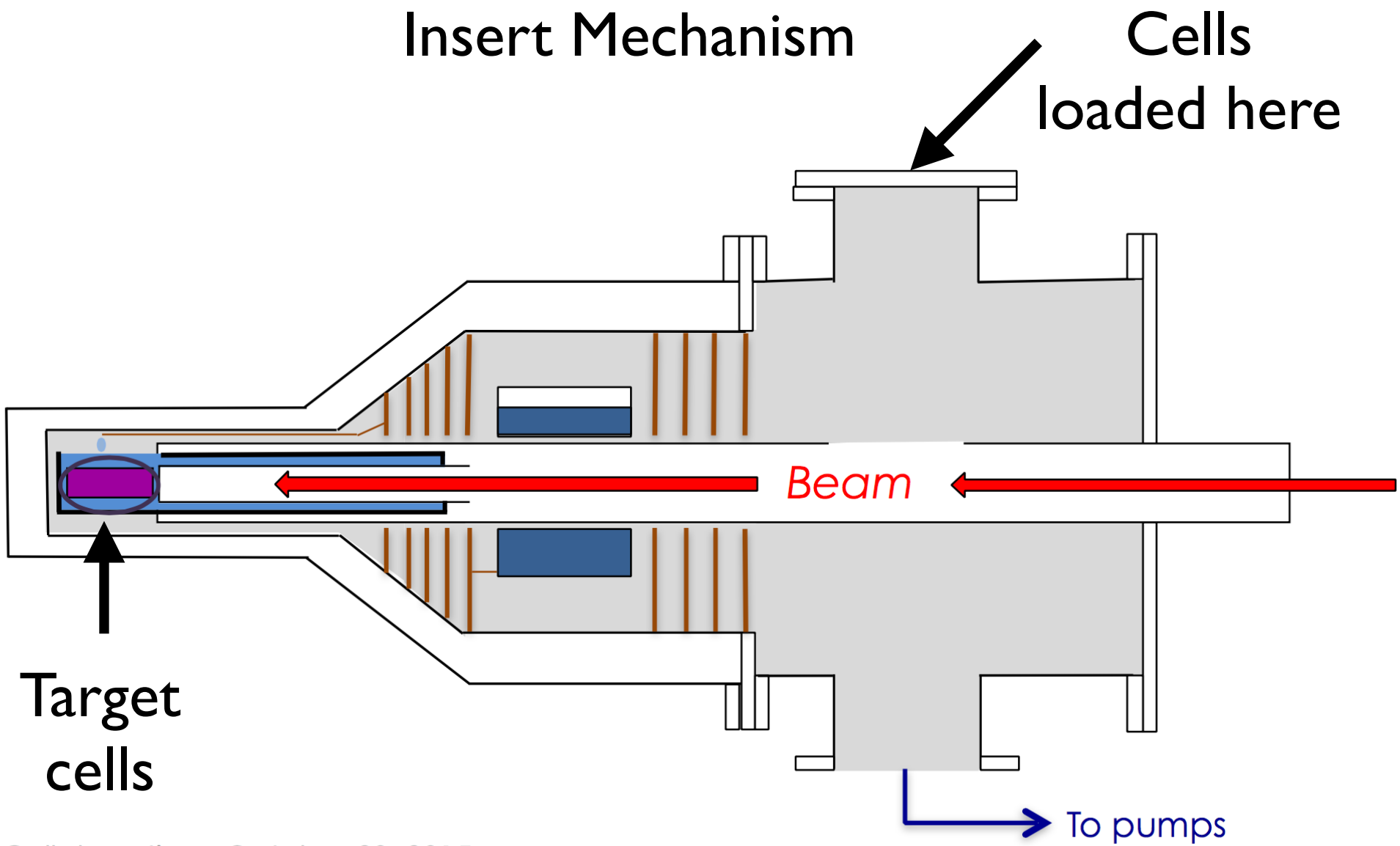
Simultaneous opposite target polarizations



Radiation pattern from the wedge.
Reflected power ~ 2 mW.

Liquid crystal microwave imaging →




Insert Mechanism
Cells loaded here
Beam
Target cells
To pumps

Update on DVCS Analysis from E1-6 Data

A. Movsisyan, S. Pisano, H. Avakian

INFN-Ferrara

Improvements in DVCS

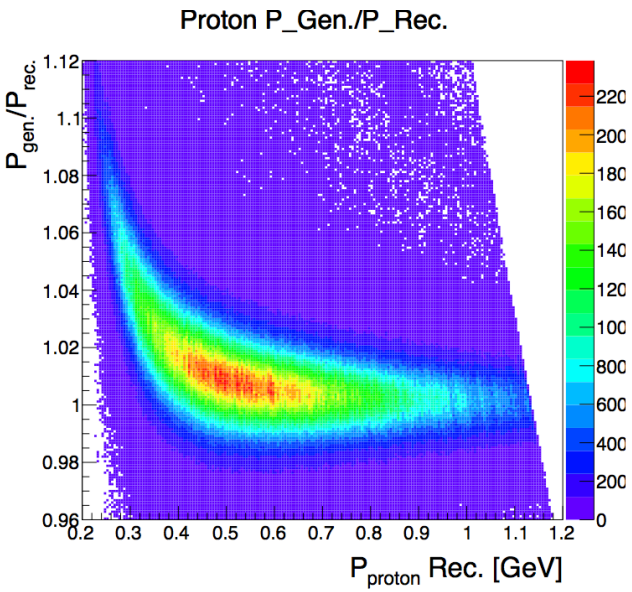
via

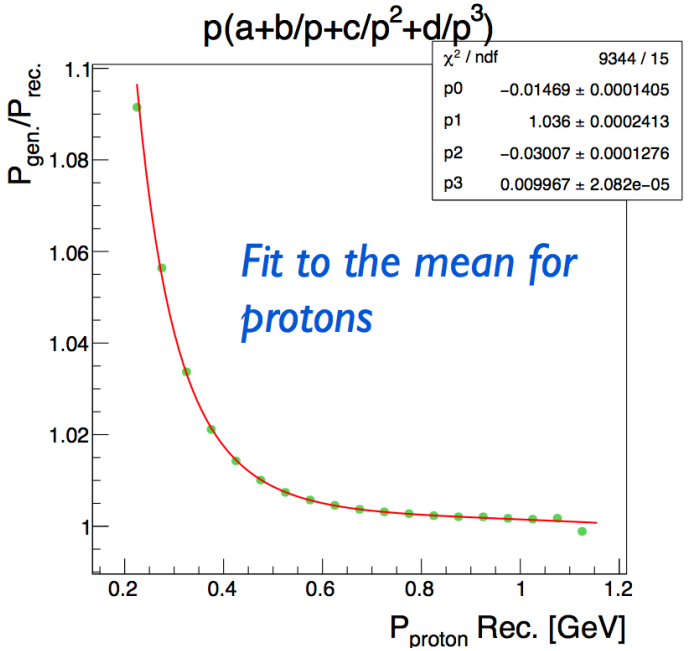
$ep(\gamma)$

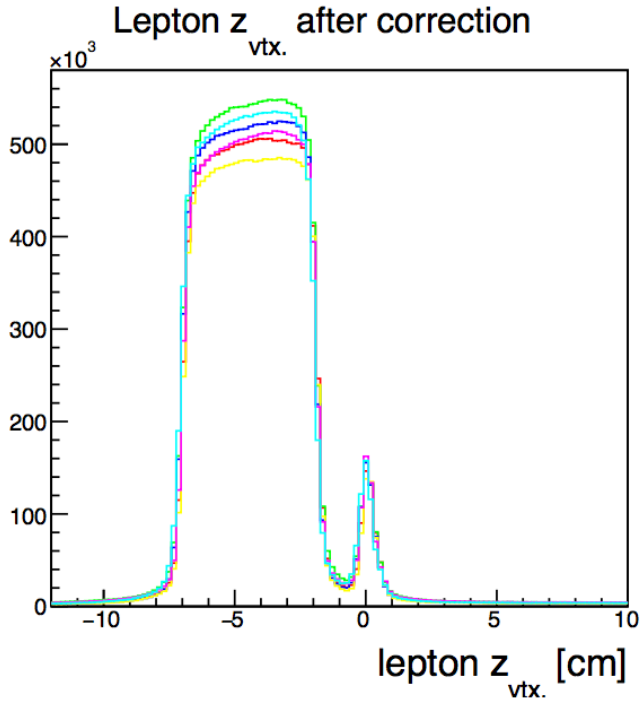
$ep\gamma$

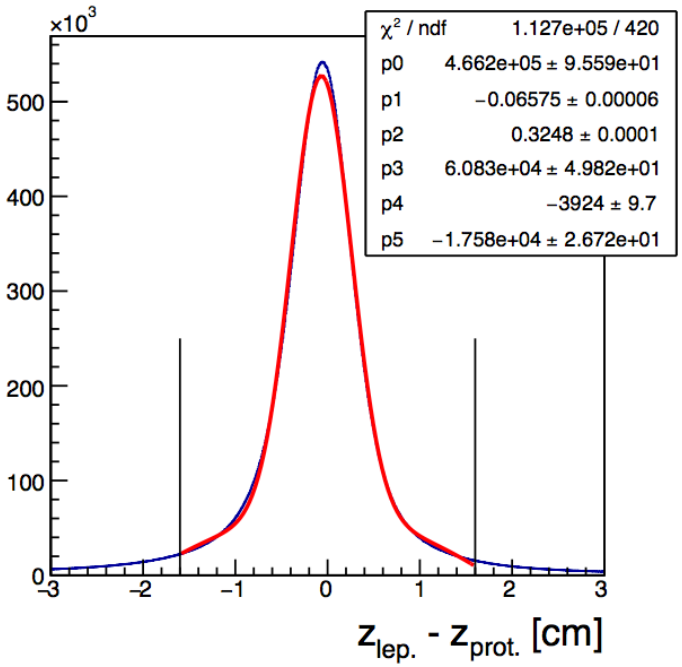
$ep\gamma\gamma(\pi^0)$

Improve: proton momentum, vertex resolution









Exclusive channels

$ep\gamma\gamma$ − sample

$W^2 > 4\ [GeV^2]$

$P_{lepton} > 0.63884\ [GeV]$

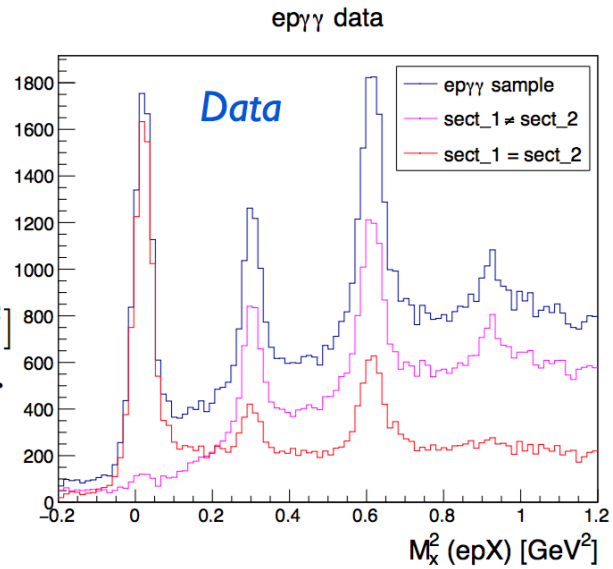
$10 \times N_{pe} > 25$

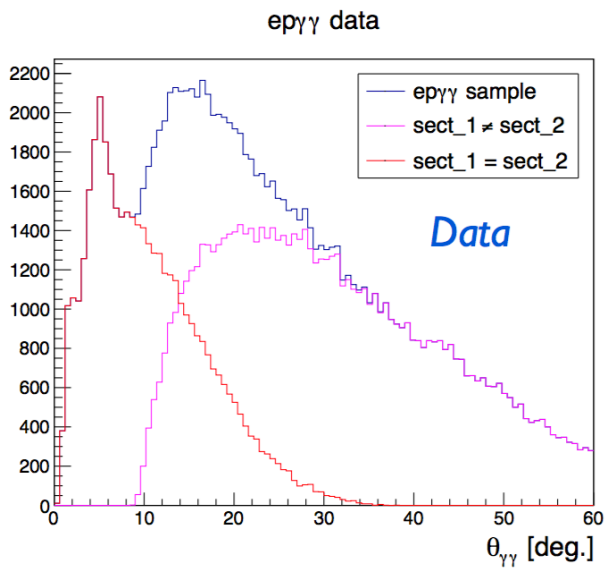
$-t < 0.52\ [GeV^2]$

$-0.05 < M_x^2(epX) < 0.09\ [GeV^2]$

Both photons in the same sector

$P_\pi > 2.2\ [GeV]$





$ep \cup ep\gamma$ − sample

$W^2 > 4\ [GeV^2]$

$P_{lepton} > 0.8\ [GeV]$

$10 \times N_{pe} > 25$

$-t < 0.52\ [GeV^2]$

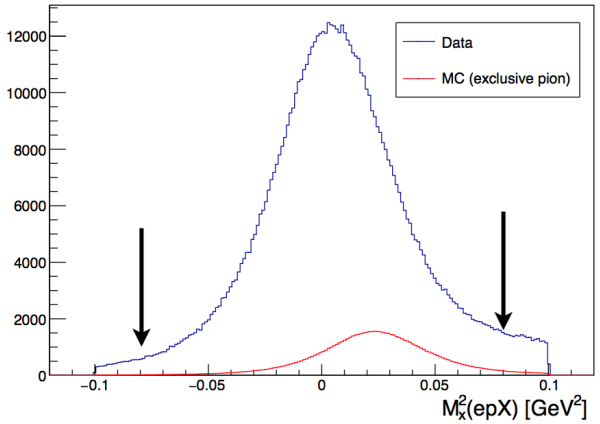
$-0.08 < M_x^2(epX) < 0.08\ [GeV^2]$

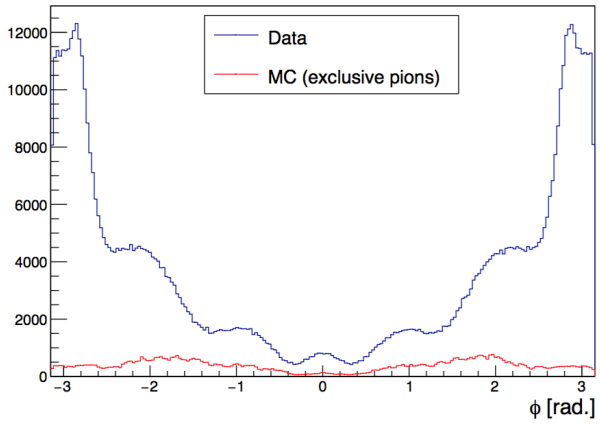
$\theta_{\gamma_{calc.}} > 1.4°$

Background contribution estimated from MC:

$$N_{0,1\gamma}^{Data\,\pi^0}(x, Q^2, -t, \phi) = \frac{N_{\pi^0}^{Data}}{N_{\pi^0}^{MC}} N_{0,1\gamma(\pi^0)}^{MC}(x, Q^2, -t, \phi)$$

Normalization factor obtained from exclusive pion analysis:



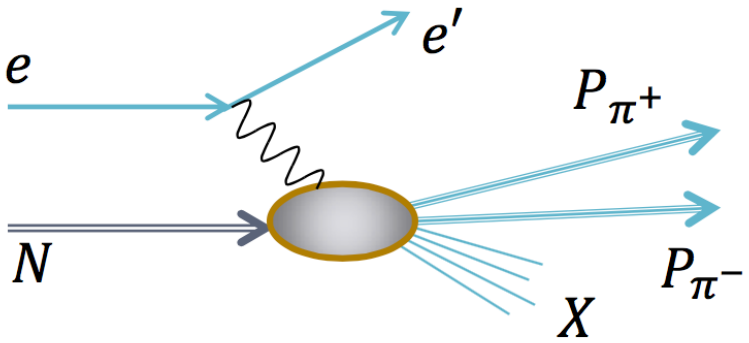


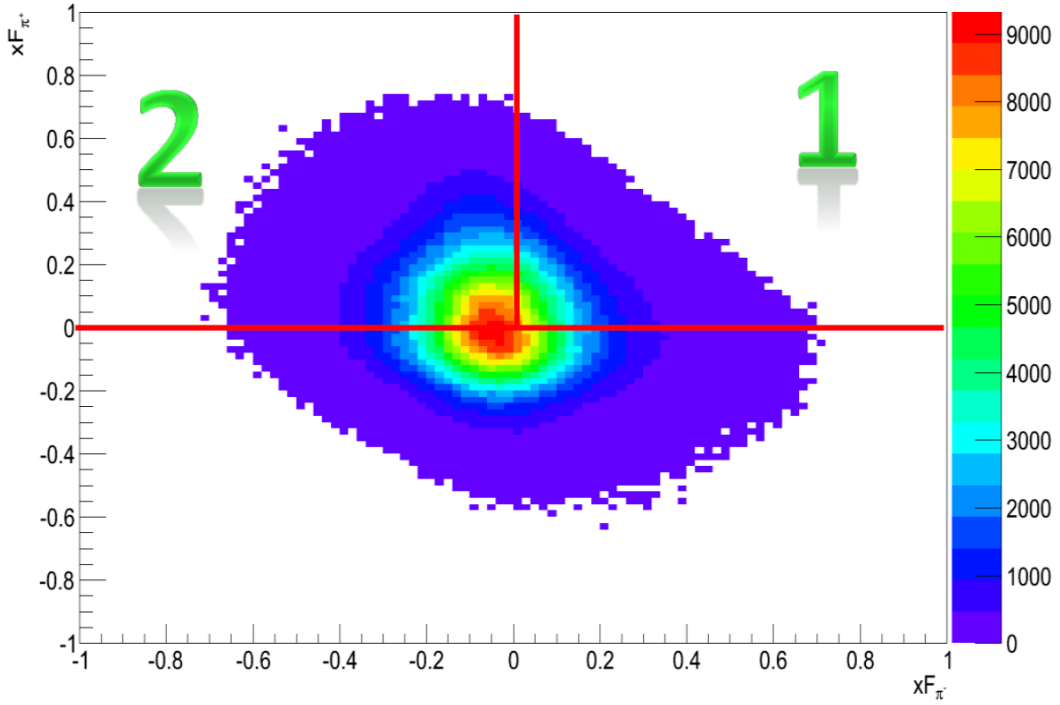
Back2back di-hadron production with CLAS 6-GeV data

Silvia Pisano*, Harut Avakian§
Laboratori Nazionali di Frascati INFN
§Jefferson Lab

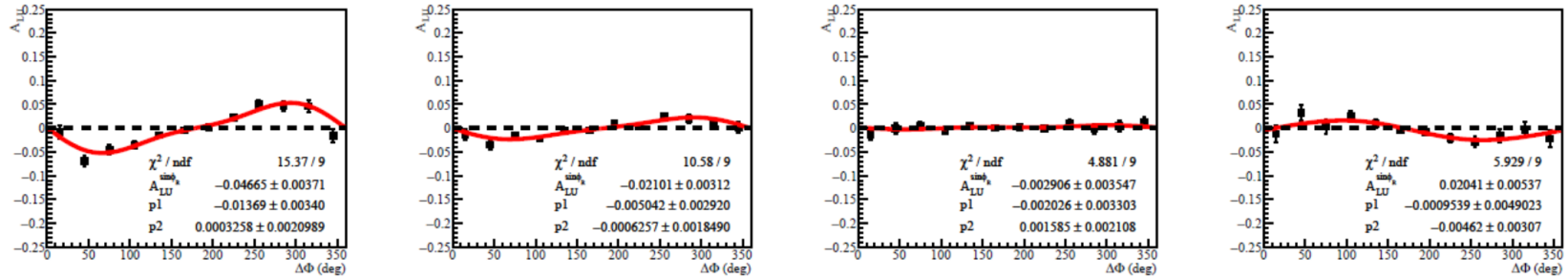
$$\mathcal{F}_{LU}^{\sin(\phi_1-\phi_2)} = \frac{|\boldsymbol{P}_{1\perp}||\boldsymbol{P}_{2\perp}|}{m_N m_2} C\left[w_5 \hat{l}_1^{\perp h} D_1\right]$$

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

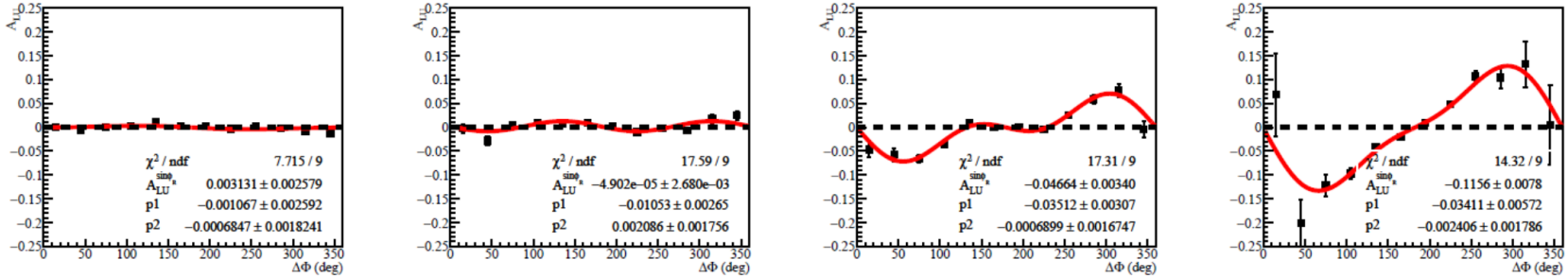




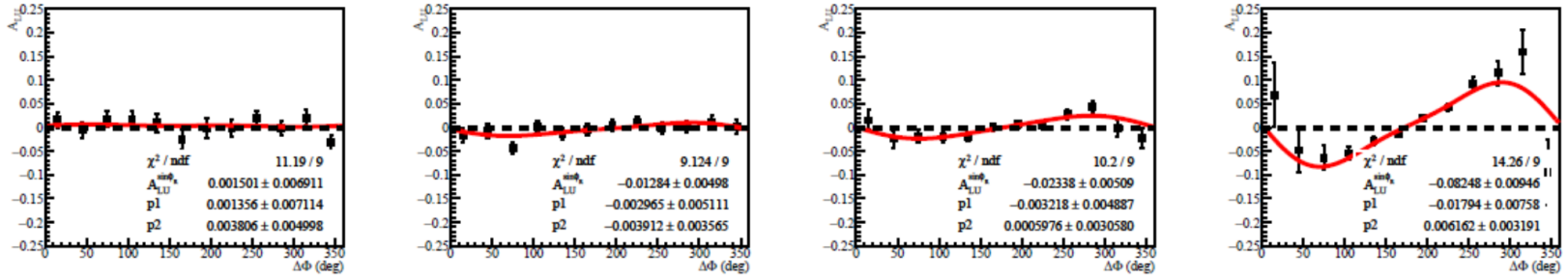
Back-to-back pion and proton: x_F-gap = $x_F(\pi^+) - x_F(p)$



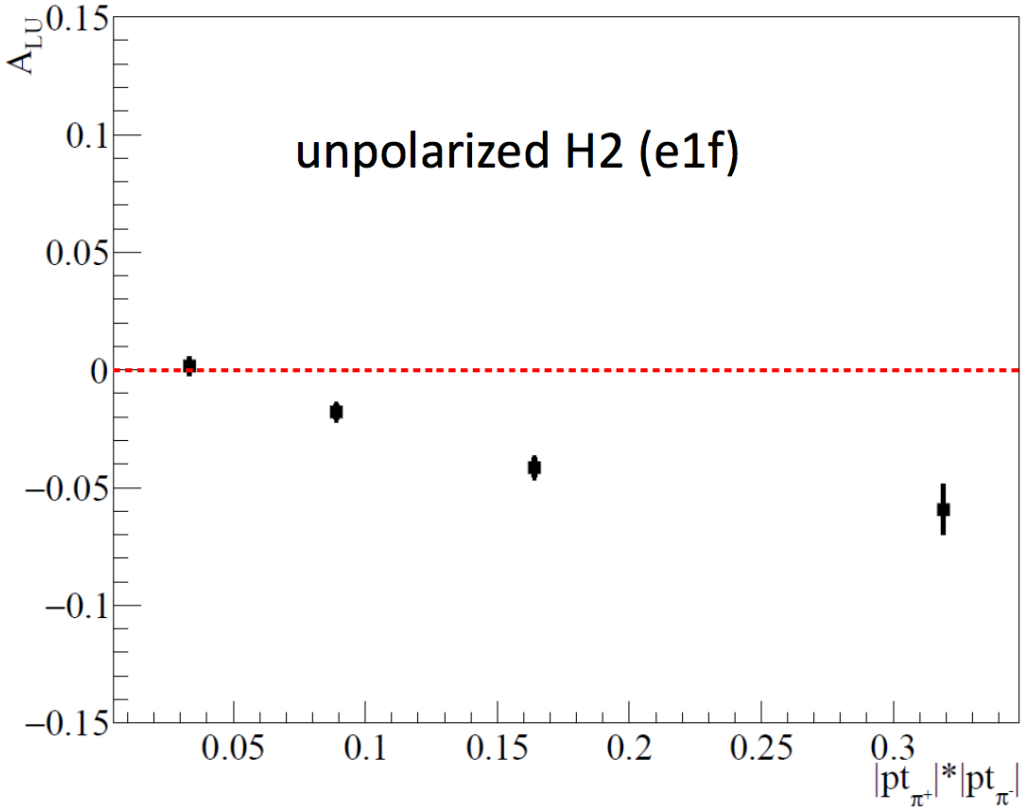
Back-to-back pion and proton: $|p_{T1}||p_{T2}|$distribution

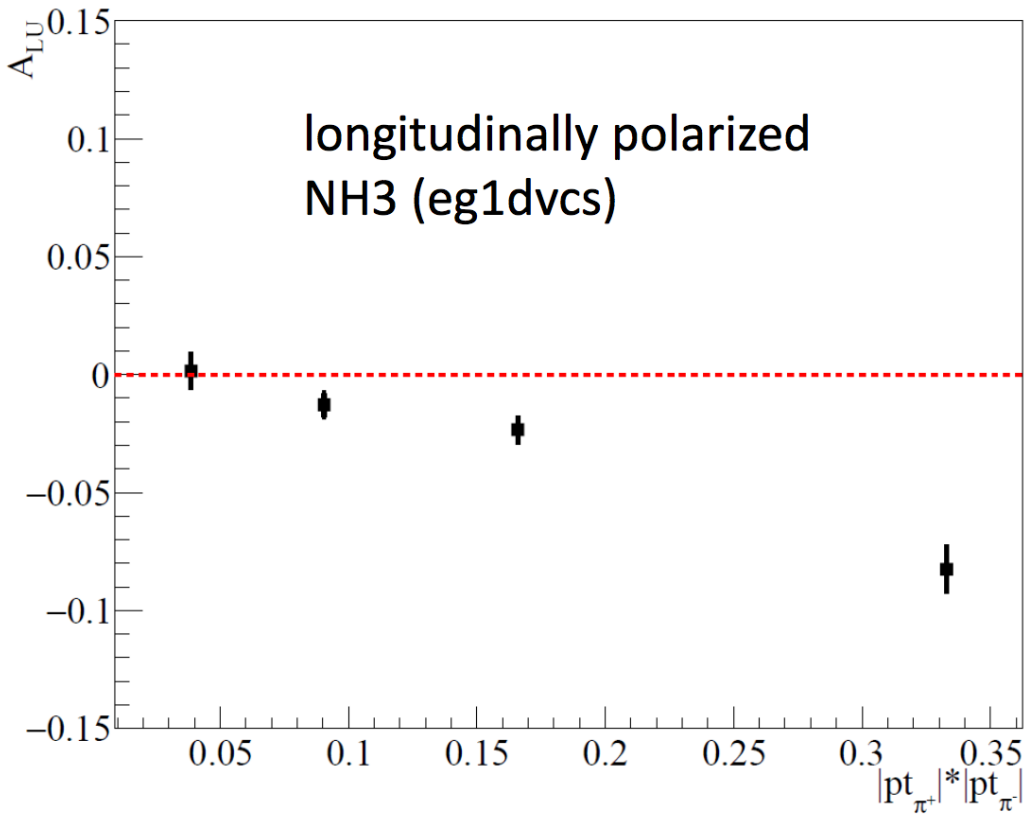


Back-to-back $ep \to ep\pi^+X$: $|p_{T1}||p_{T2}|$ on NH3 (eg1dvcs)



Beam Single Spin Asymmetries
Similarities between p and A targets

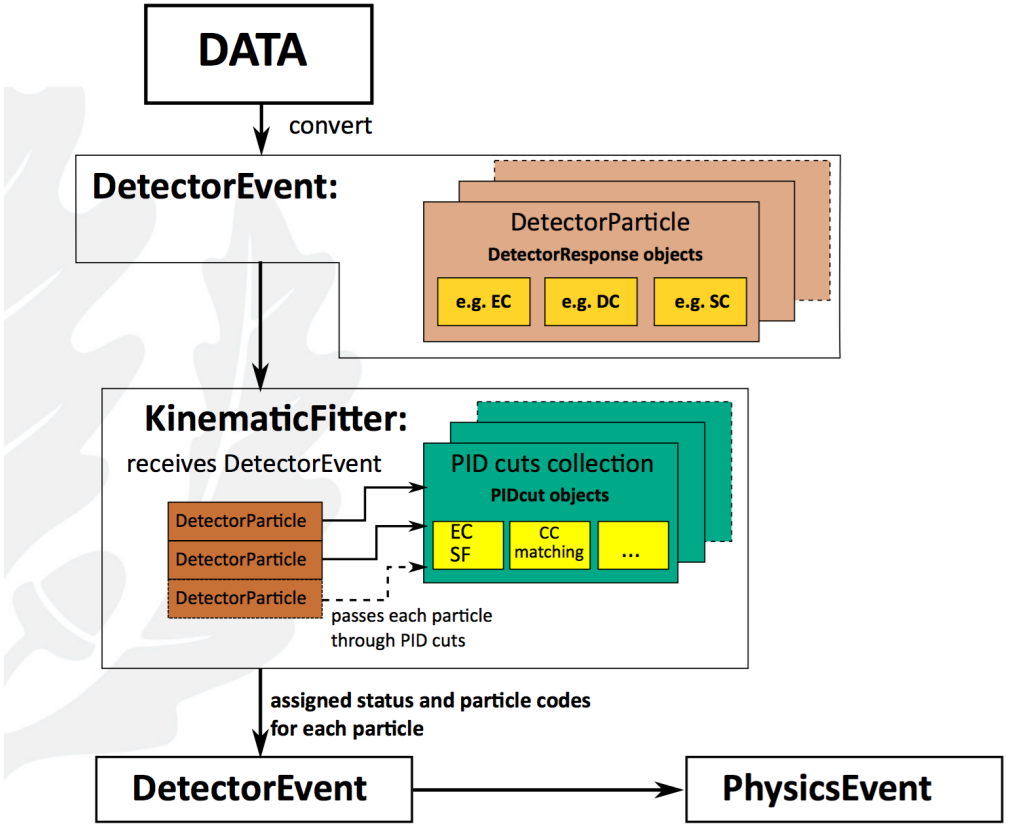




Interesting new observables for TMD structure

CLAS12 SOFTWARE APPLICATION to eg1-dvcs data

A. Kim



Custom PID: TOF beta

pTOFbeta.java

```java
package org.jlab.clas6.eg1dvcs.kenjo;

import static java.lang.Math.abs;
import static java.lang.Math.sqrt;
import org.jlab.clas.detector.DetectorType;
import org.jlab.clas.physics.*;

/**
 *
 * @author kenjo
 */

public class pTOFbeta implements IDetectorParticleProcessor{
    @Override
    public boolean processParticle(DetectorParticle detpart, DetectorEvent detevent) {

        DetectorResponse scres = detpart.getResponse(DetectorType.SC, 0);

        if (scres != null) {
            double rsc = scres.getPath();
            double tsc = scres.getTime();
            double beta = rsc/(tsc-detevent.getStartTime())/30;
            detpart.addProperty("beta before cut", beta);

            double mom=detpart.vector().mag();
            double dbeta = beta - mom/sqrt(mom*mom+0.985*0.985);

            if(abs(dbeta)<0.05){
                detpart.addProperty("beta after cut", beta);
                return true;
            }
        }
        return false;
    }
}
```

1

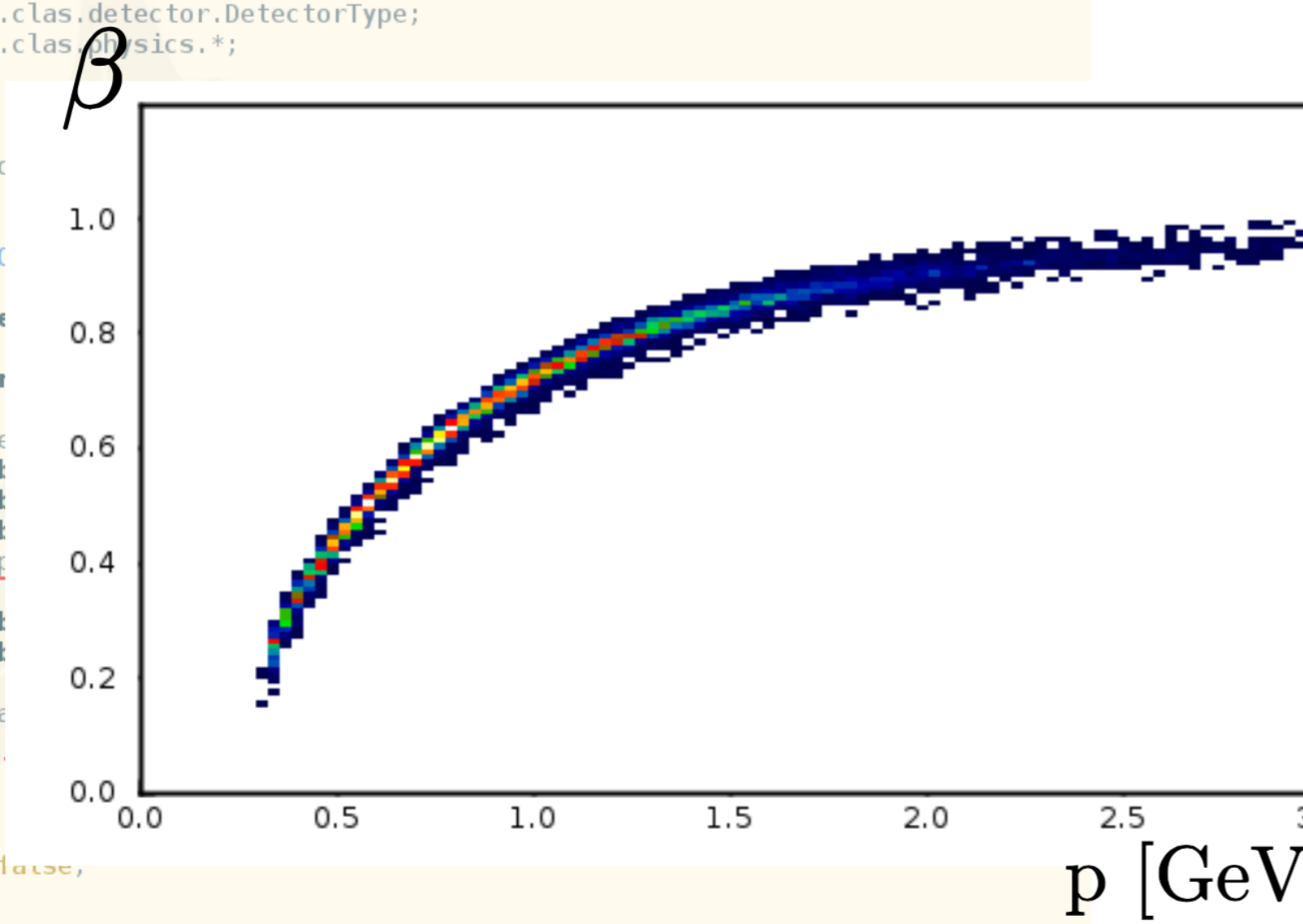
2

Simple, transparent, shareable, common analysis rubric for 6 and 12 GeV

Custom PID: TOF beta

pTOFbeta.java

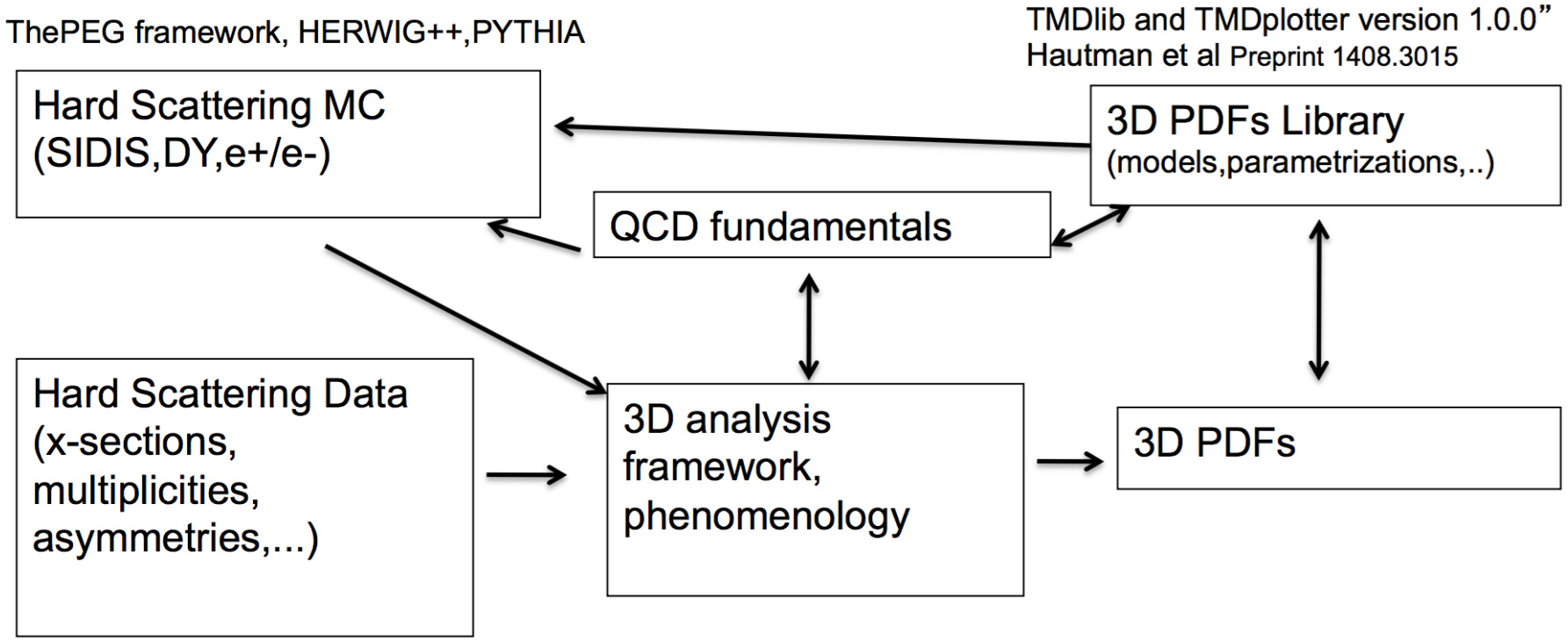
```
1  package org.jlab.clas6.eg1dvcs.kenjo;
2
3  import static java.lang.Math.abs;
4  import static java.lang.Math.sqrt;
5  import org.jlab.clas.detector.DetectorType;
6  import org.jlab.clas.physics.*;
7
8  /**
9   *
10  * @author kenjo
11  */
12
13 public class pTO
14     @Override
15     public boole
16
17         Detector
18
19         if (scre
20             doub
21             doub
22             doub
23             detp
24
25             doub
26             doub
27
28             if(a
29
30
31             }
32         }
33         return false;
34     }
35 }
```



Development of a framework for TMD extraction from SIDIS data

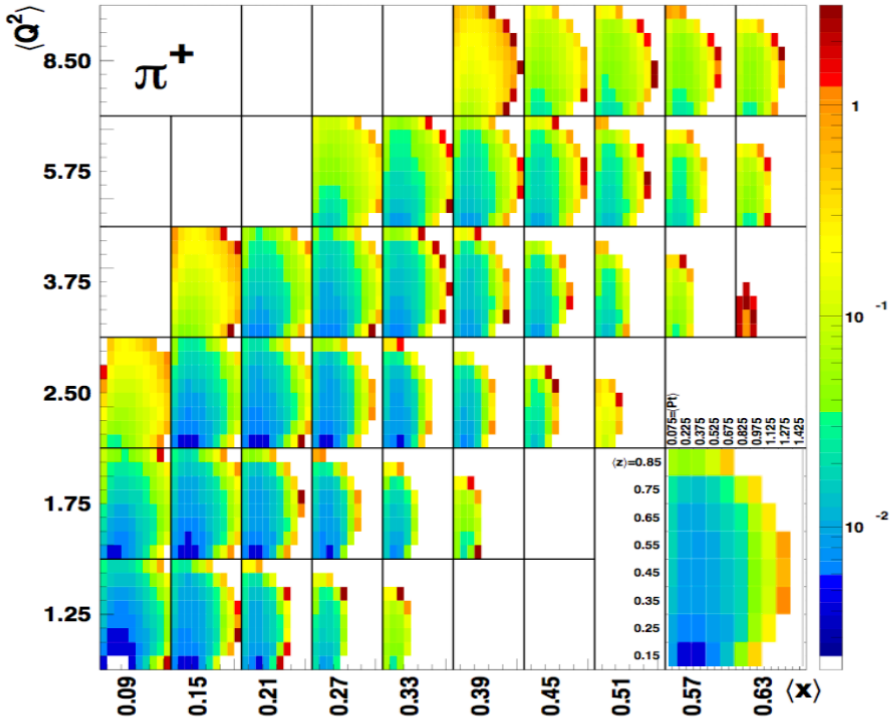
Harut Avakian (JLab)

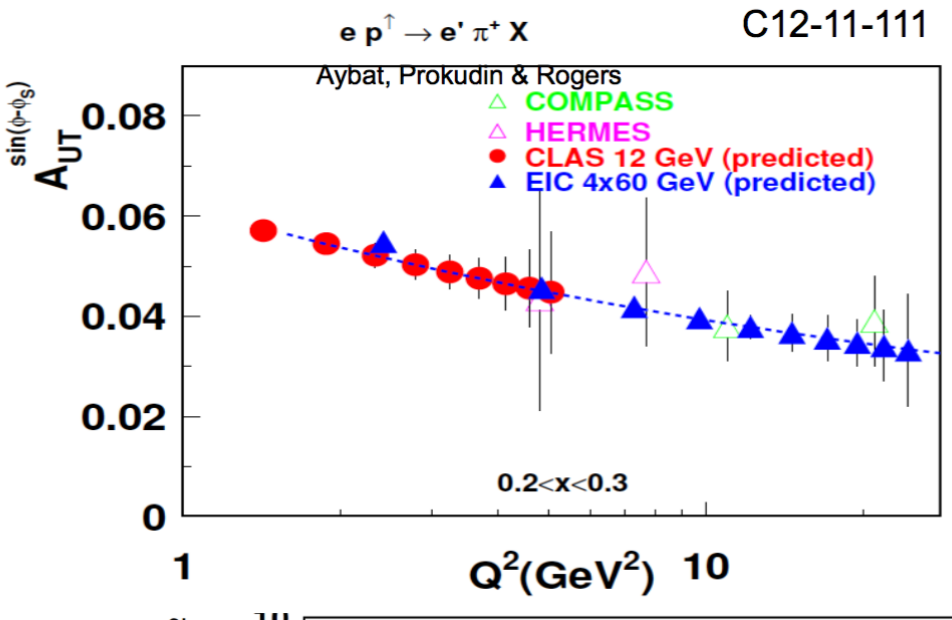
Extraction of 3D PDFs

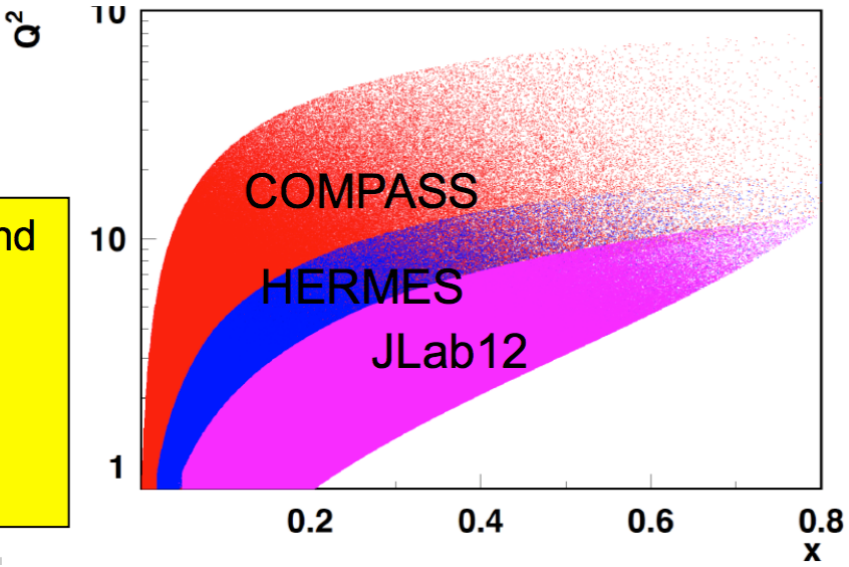


Multiple data sets will feed into TMD determinations

CLAS12 A_{UT} with transverse proton target





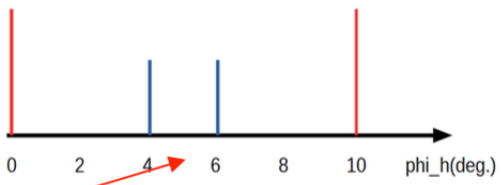


- Large acceptance of CLAS12 allows studies of P_T and Q^2-dependence of SSAs in a wide kinematic range
- Comparison of JLab12 data with HERMES, COMPASS (and EIC) will be important in understanding the Q^2 evolution and checking the theory framework.

Input data for analysis framework

- Differential input (SIDIS): M. Aghasyan et al arXiv:1409.0487 (JHEP)

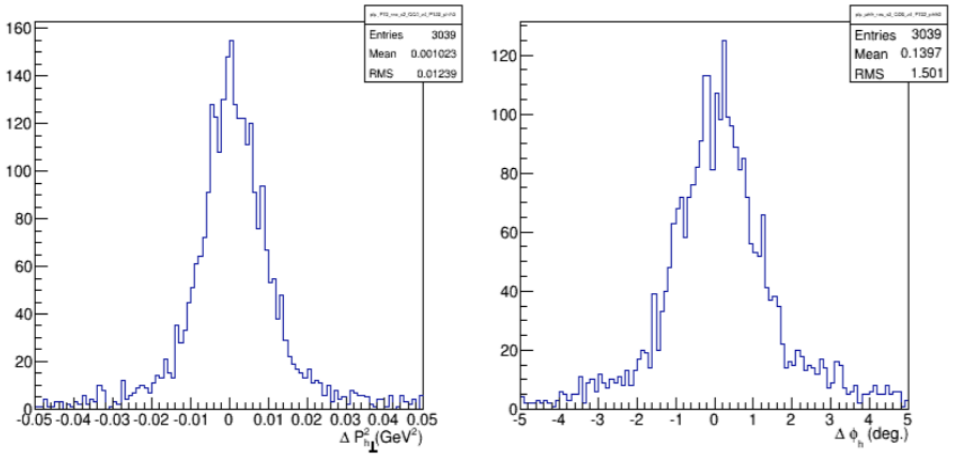
bin#	x	Q^2	y	W	M_X	ϕ	z	P_T	λ	Λ	N(counts)	RC
1 … N												



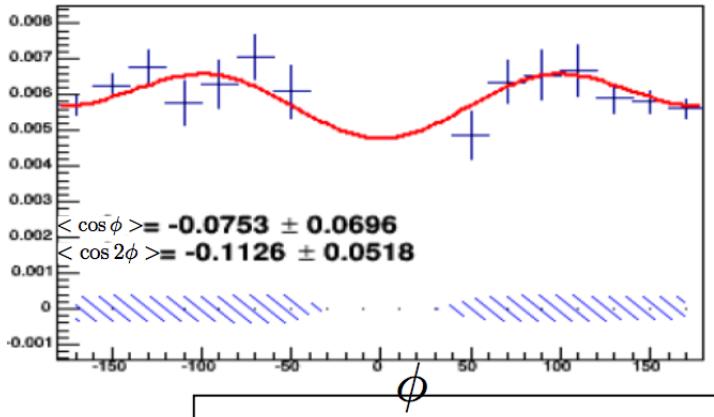
Microscopic vs macroscopic bins

Pros:
1) can go to wider bins,
2) smaller bin centering corrections
3) smaller acceptance/radiative correcions. 2)……
……

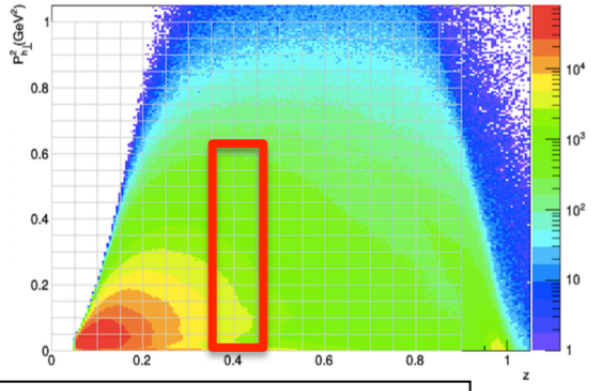
Cons:
1)Requires huge MC sample

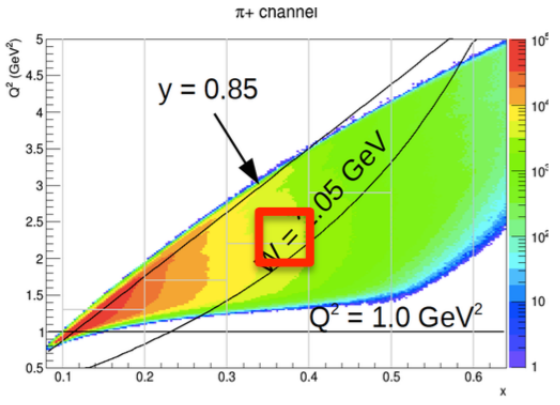


N.Harrison (preliminary e1f)



bin sizes limited by resolutions





Realistic MC is crucial for acceptance!!!

For precision studies of TMD(CFF) we need

Theory:

- Extraction framework with controlled systematics (build in validation mechanism) to define requirements for the input
- Better understanding of higher twists (indispensable part of SIDIS analysis) is crucial for interpretation of SIDIS leading twist observables
- Better understanding of Radiative Corrections (in 5D)
- Understanding of kinematic corrections (finite phase space,target mass,…)
- Understanding of target fragmentation and correlations between hadrons in target and current fragmentation
- Understanding of relative scales, sizes and kinematic dependences of different contributions

Experiment:

Realistic MC description of measured distributions to minimize acceptance effects

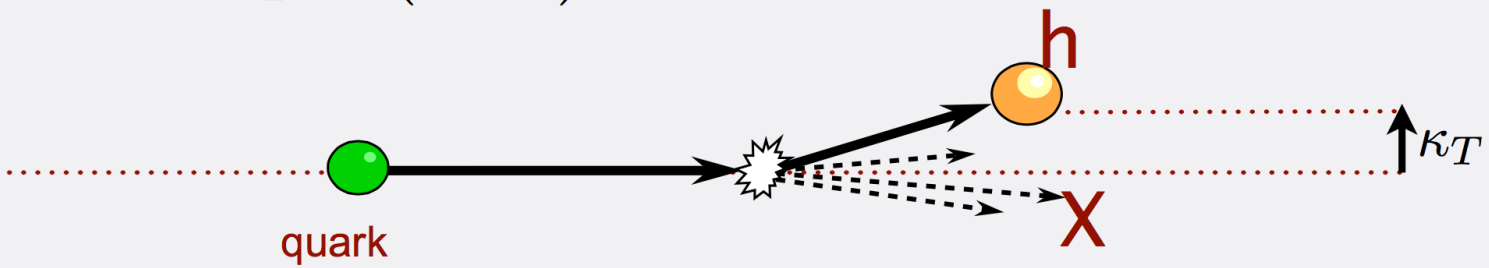
Need a new MC generator "PYTHIA with spin-orbit correlations"
to simulate azimuthal and spin correlations in final state hadronic distributions.

Proposal for topical collaboration: https://www.overleaf.com/2474182rxzqcg#/6457247/

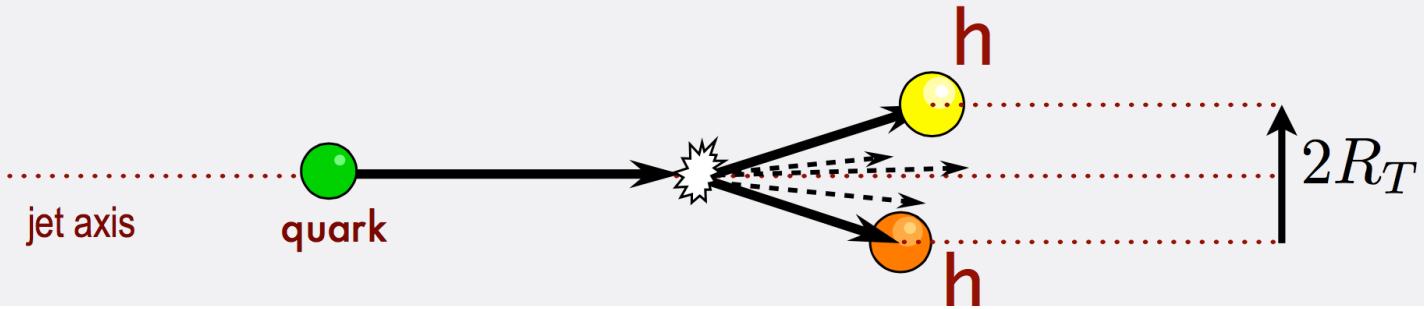
PHENOMENOLOGY OF DIHADRON FRAGMENTATION FUNCTIONS AT CLAS12

Aurore Courtoy
CINVESTAV/CONACyT (Mexico)

$$D_1^{q\to h}\left(z,\kappa_T^2\right)$$



$$D_1^{q\to h_1 h_2}\left(z_1,z_2,R_T^2\right)$$



SIDIS-single hadron

$$d\sigma \propto \sum_q \left[\mathrm{PDF}^q \otimes \mathrm{FF}^q\right](x, z, P_{h\perp}^2)$$

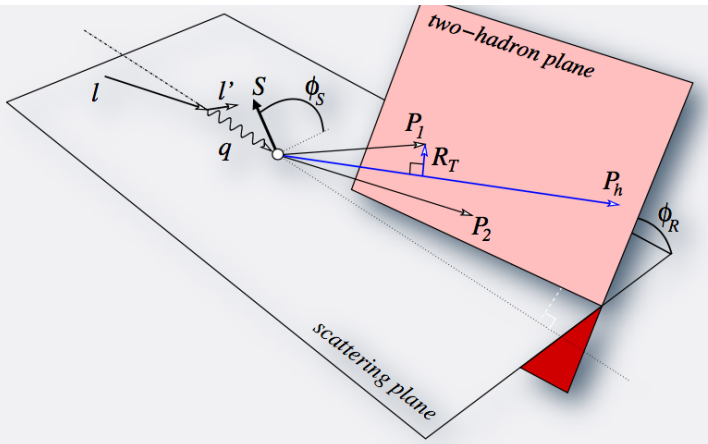
- TMD Fragmention and Distribution functions
- Convolution
- More Lorentz structures
- 3D ``tomography"

SIDIS-dihadron

$$d\sigma \propto \sum_q \mathrm{PDF}^q(x) \times \mathrm{DiFF}^q(z, M_h)$$

- Collinear Distribution functions
- Simple product
- 1D ``tomography"
- 2pion physics

DIHADRON SIDIS



☑ **A_{UT}** **@ HERMES & COMPASS**
@ CLAS12 & SoLID

$$A_{UT}^{\sin(\phi_R+\phi_S)\,\sin\theta}(x,y,z,M_h;Q) = -\frac{B(y)}{A(y)}\,\frac{|\mathbf{R}|}{M_h}\,\frac{\sum_q e_q^2\, h_1^q(x;Q^2)\, H_{1,sp}^{\sphericalangle\, q}(z,M_h;Q^2)}{\sum_q e_q^2\, f_1^q(x;Q^2)\, D_1^q(z,M_h;Q^2)}$$

[Jaffe, Jin, Tiang, PRL 80]
[Radici, Jakob & Bianconi, PRD65]

☑ **A_{LU} @CLAS**

$$A_{LU}^{\sin\phi_R\,\sin\theta}(x,y,z,M_h,Q) = -\frac{W(y)}{A(y)}\,\frac{M}{Q}\,\frac{1}{2}\,\frac{|\mathbf{R}|}{M_h}\,\frac{\sum_q e_q^2\left[x e^q(x)\, H_{1,sp}^{\sphericalangle,q}(z,M_h) + \frac{M_h}{zM}\, f_1^q(x)\,\tilde{G}_{sp}^{\sphericalangle,q}(z,M_h)\right]}{\sum_q e_q^2\, f_1^q(x)\, D_{1,ss+pp}^q(z,M_h)}$$

[Bacchetta & Radici, PRD69]

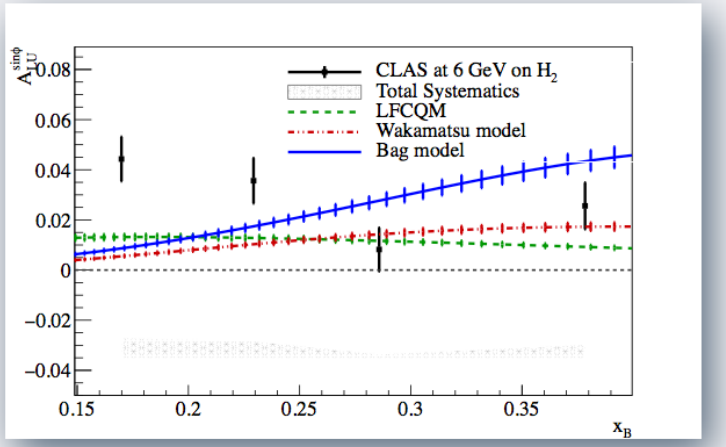
☑ **A_{UL} @CLAS**

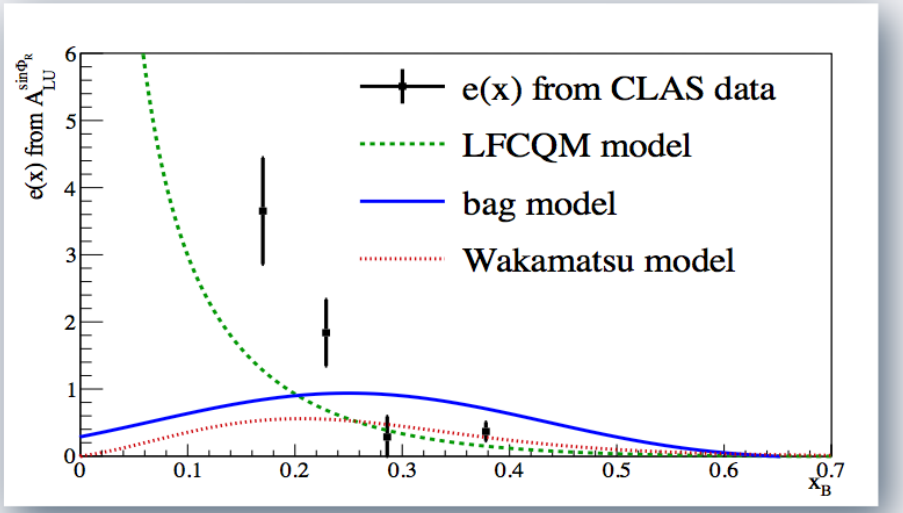
$$A_{UL}^{\sin\phi_R\,\sin\theta}(x,y,z,M_h,Q) = -\frac{V(y)}{A(y)}\,\frac{M}{Q}\,\frac{1}{2}\,\frac{|\mathbf{R}|}{M_h}\,\frac{\sum_q e_q^2\left[x h_L^q(x)\, H_{1,sp}^{\sphericalangle,q}(z,M_h) + \frac{M_h}{zM}\, g_1^q(x)\,\tilde{G}_{sp}^{\sphericalangle,q}(z,M_h)\right]}{\sum_q e_q^2\, f_1^q(x)\, D_{1,ss+pp}^q(z,M_h)}$$

FIRST TRY EXTRACTION

Assume no dynamical higher-twist in the fragmentation part

In search of e(x)





leading-twist DiFFs known from PAVIA fit

$$A_{LU}^{\sin\phi_R}(x_i, m_{\pi\pi\,i,}, z_i; Q_i, y_i) = -\frac{W(y_i)}{A(y_i)}\,\frac{M}{Q_i}\,\frac{x_i\left[\frac{4}{9}e^{u_V}(x_i,Q_i^2) - \frac{1}{9}e^{d_V}(x_i,Q_i^2)\right] n_{u,i}^{\uparrow}(Q_i^2)}{\sum_{q=u,d,s} e_q^2 f_1^q(x_i,Q_i^2)\, n_{q,i}(Q_i^2)}$$

[AC et al, arXiv:1405.7659]

Status report on SIDIS dihadron asymmetries from the eg1-dvcs experiment

- $e\,p \to e'\,\pi^+\,\pi^-\,X$
- $e\,p \to e'\,\pi^+\,\pi^0\,X \to e'\,\pi^+\,\gamma\gamma X$

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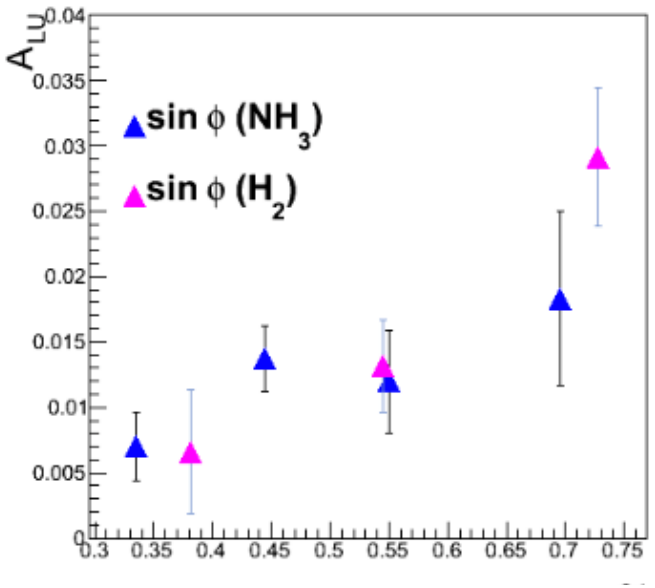
$$F_{LU}^{\sin\phi_R} = -x\frac{|\boldsymbol{R}|\sin\theta}{Q}\left[\frac{M}{M_h}\,x\,e^q(x)\,H_1^{\sphericalangle\,q}(z,\cos\theta,M_h) + \frac{1}{z}\,f_1^q(x)\,\widetilde{G}^{\sphericalangle\,q}(z,\cos\theta,M_h)\right],$$

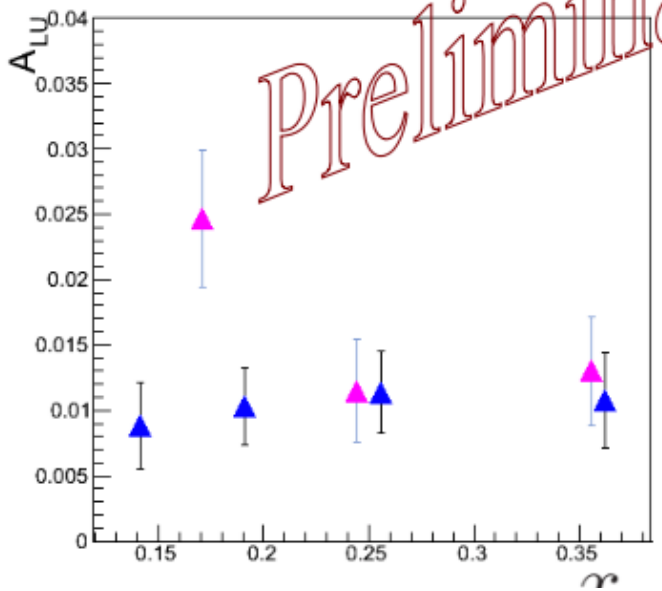
$$F_{UL}^{\sin\phi_R} = -x\frac{|\boldsymbol{R}|\sin\theta}{Q}\left[\frac{M}{M_h}\,x\,h_L^q(x)\,H_1^{\sphericalangle\,q}(z,\cos\theta,M_h) + \frac{1}{z}\,g_1^q(x)\,\widetilde{G}^{\sphericalangle\,q}(z,\cos\theta,M_h)\right],$$

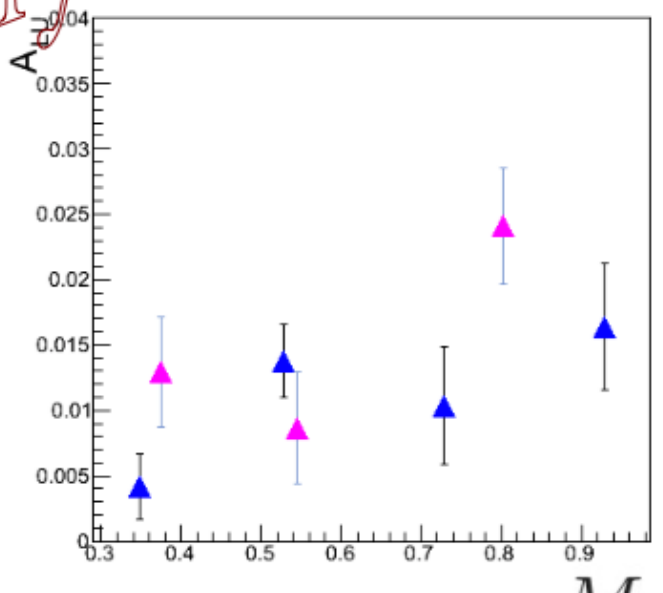
$$F_{LL} = x g_1^q(x)\,D_1^q(z,\cos\theta,M_h),$$

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

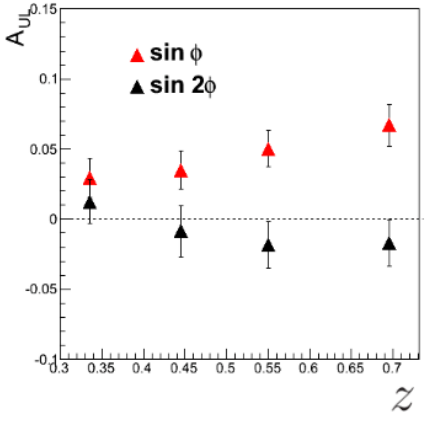
$$A_{LU} \propto e(x) H_1^{\sphericalangle q}(z, \cos\theta, M_h)$$

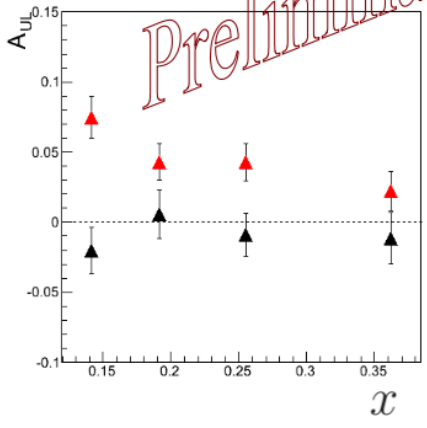


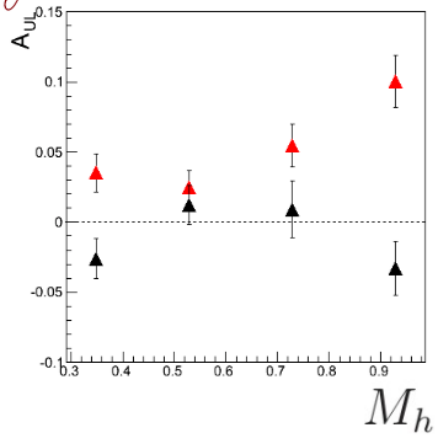




Preliminary







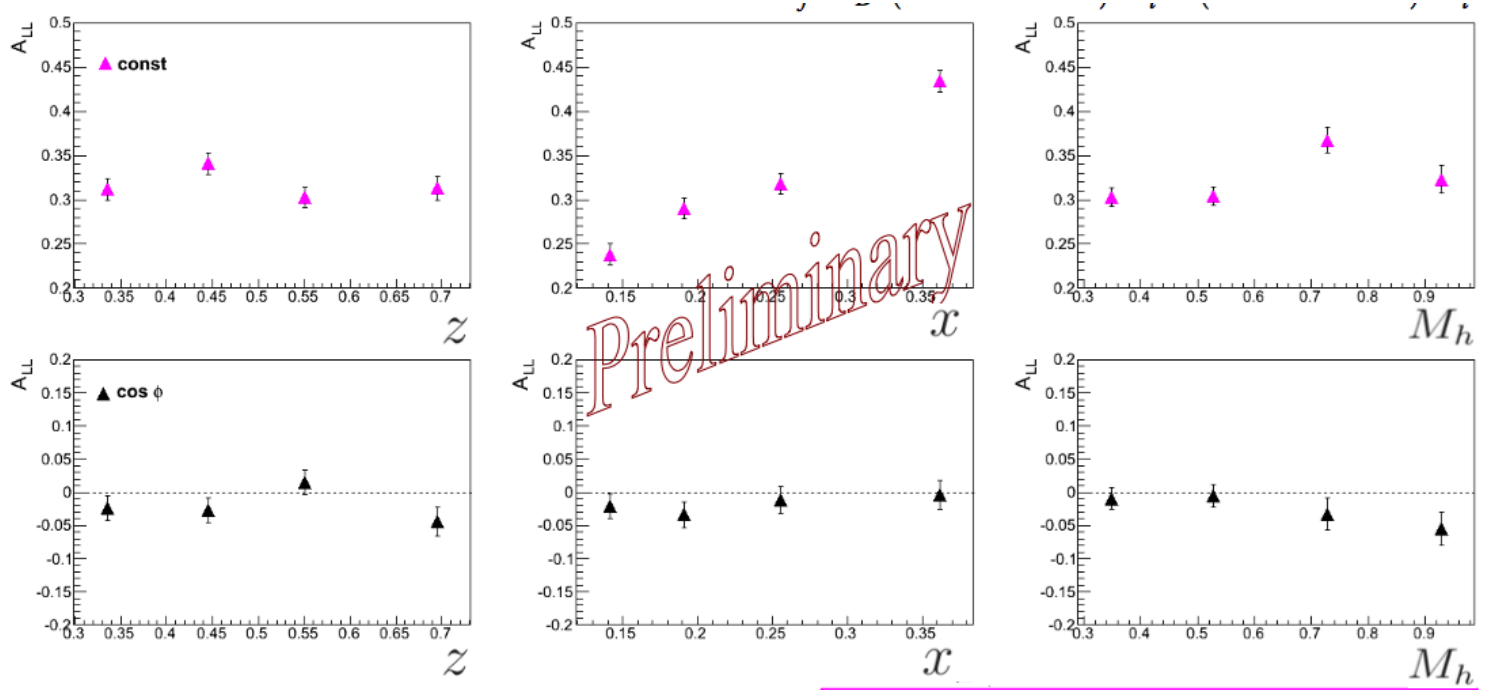
Preliminary

A_{LU} (top)
A_{UL} (bot)

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

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

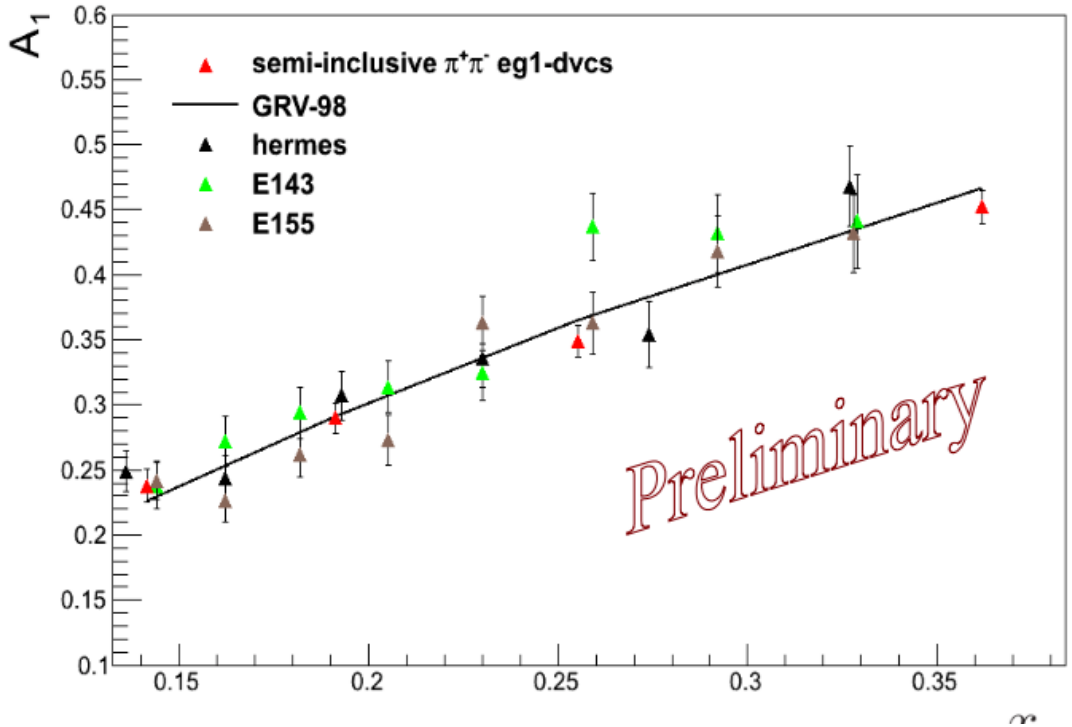
A_{LL}



- Significantly non-zero A_{LL}^{const} asymmetries
- DF = 0.18 has been used

$$A_{LL}^{const} \propto g_1(x) D_1^q(z, \cos\theta, M_h)$$

$$A_{LL}^{\cos\varphi_R} \propto g_1(x) \tilde{D}^{\sphericalangle q}(z, \cos\theta, M_h)$$



A_{LL}

A_{LL} agrees with A_1

- DPWG analyses are working their way through the system
- CLAS & CLAS12 data are starting to be analyzed in a common framework
- Analysis/extraction frameworks are needed for SIDIS and DVCS