

Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, 8th March 2019

Publications:

CLAS 2018-5

Measurement of the beam spin asymmetry of the $ep \rightarrow e'p\eta$ in the deep-inelastic regime with CLAS,
B.Zhao, published on Phys. Lett. B

Ad Hoc Reviews

Analysis	Data	Lead Author	In progress
Exploring the structure of the proton via semi-inclusive pion electroproduction	e1f	N. Harrison K. Joo	2nd round done on Jan 19

Analysis Reviews

Analysis	Data	Author	In progress
Extraction of $A_{LU}^{\sin\phi}$ moments from hard exclusive π^+ off the unpolarized hydrogen target in a wide range of kinematics	e1f	S. Diehl	2 nd round done on Feb 19
First Observations of Beam Spin Asymmetries for K+	e1f	D. Riser	1 st round done on Sep 18
Beam asymmetries in exclusive π^+ electro production for $W > 1.7$ GeV from e16	e16	P. Bosted K. Park	Analysis under revision
Di-hadron beam spin asymmetry in SIDIS electro production	eg1-dvcs	M. Mirazita O. Soto	Analysis under revision
Semi-inclusive pion production	e16	M. Osipenko	Working on a better alignment

Analysis Reviews

Analysis	Data	Author	In progress
Deep-virtual production of the ρ^+ meson off the proton	e1-dvcs	A. Fradi	Ahmed willing to continue
Exclusive electro-production of the $f_0(980)$ and $f_2(1270)$ on the proton with CLAS	e1f	B. Garillon S. Niccolai	Brice busy with other project
Time-like Compton scattering	g12	I. Abayrak	Last record 2015

CAA Reviews

Analysis	Data	Author	In progress
Observation of transverse polarization of Lambda hyperons in the current fragmentation from unpolarized targets	RGA	A. Vossen C. Dilks	1 st round done on Oct 18
Boer-Mulders effect and helicity dependent fragmentation functions in hadron pair production off unpolarized targets	RGA	A. Vossen C. Dilks	1 st round done on Oct 18

08:30 - 10:00

Deep Processes Working Group - I

<https://bluejeans.com/551610659>

Convener: Mr. Marco Contalbrigo (INFN Ferrara)

Location: F113

08:30 DPWG Business 5'

Speaker: Mr. Marco Contalbrigo (INFN Ferrara)

Material: **Slides** 

08:35 Di-hadron beam spin asymmetry with CLAS data 15'

Speaker: marco mirazita (inf n laboratori nazionali di frascati)

Material: **Slides** 

08:50 Correlated di-hadron production 20'

Speaker: Dr. Harut Avagyan (Jefferson Lab)

Material: **Slides** 

09:10 Single-hadron analysis on DNP data 20'

Speaker: Dr. Stefan Diehl (University of Connecticut)

Material: **Slides** 

09:30 pi0 SIDIS Multiplicity on DNP data 10'

Speaker: Giovanni Angelini (GWU)

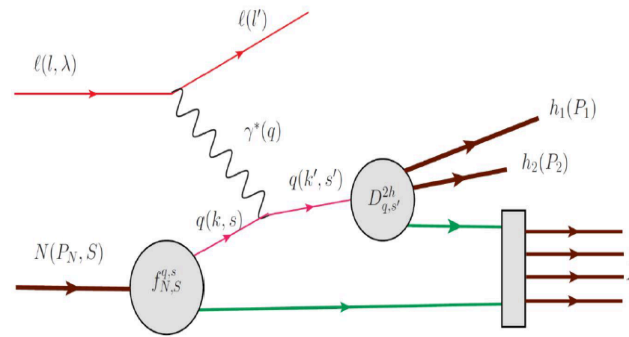
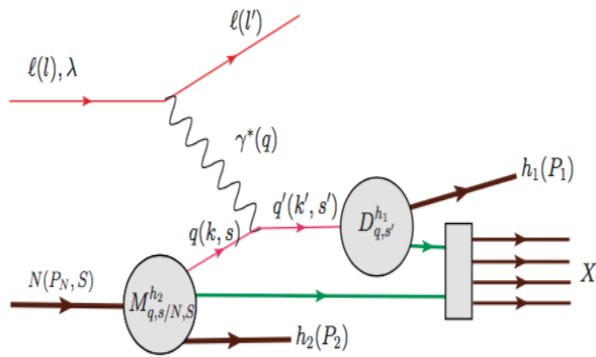
Material: **Slides** 

09:40 MC plans for SIDIS analyses 20'

Speaker: Mr. Marco Contalbrigo (INFN Ferrara)

Correlated di-hadron production

Harut Avakian (JLab)



$$P_h = P_1 + P_2,$$

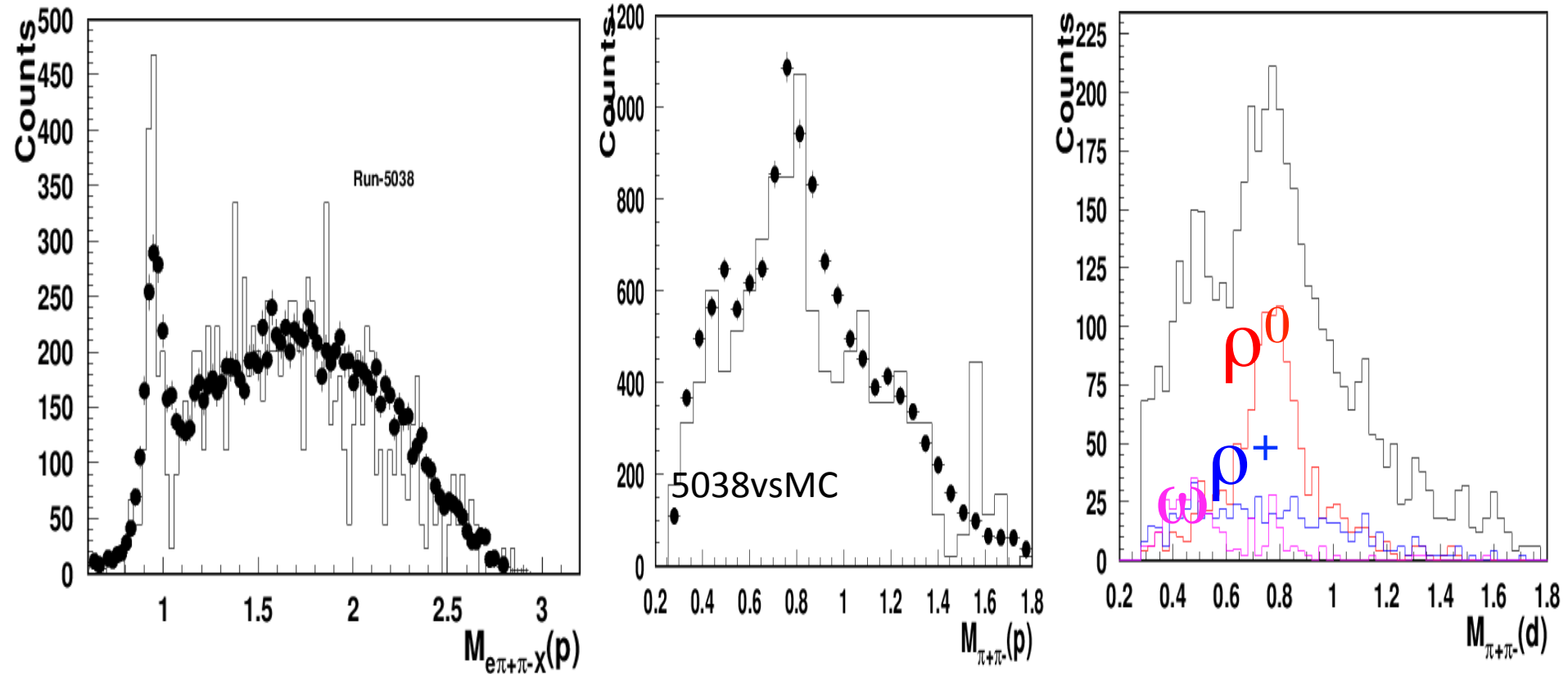
$$R = \frac{1}{2}(P_1 - P_2).$$

Beam SSA provides access to quark helicity in SIDIS via dihadron correlations using the helicity-dependent dihadron fragmentation function (DiFF)

Dedicated CLAS12 proposals: E12-06-112B/E12-09-008B

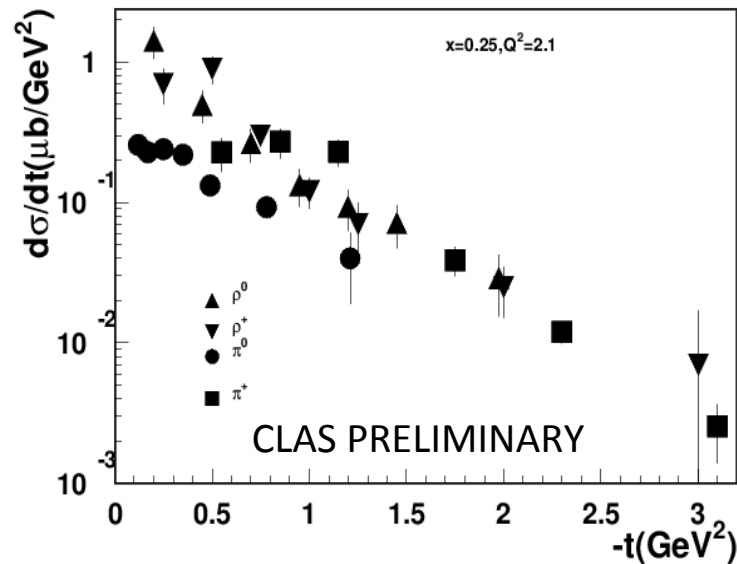
Correlated pairs: Data/MC(Run 5038,T-1,10.6GeV)

Data/MC normalization by number of reconstructed e^+X events



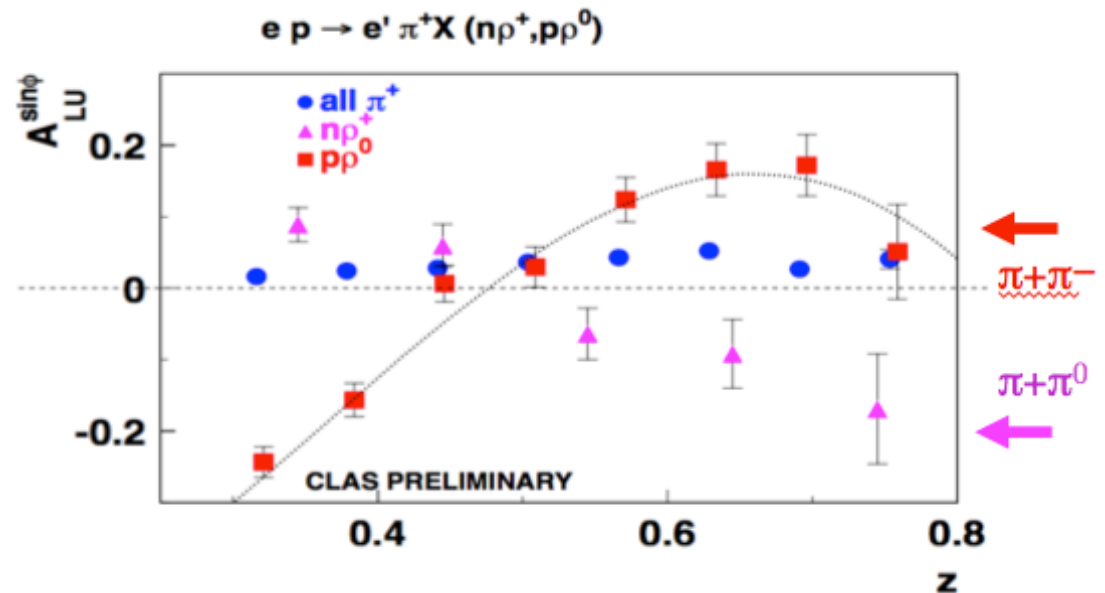
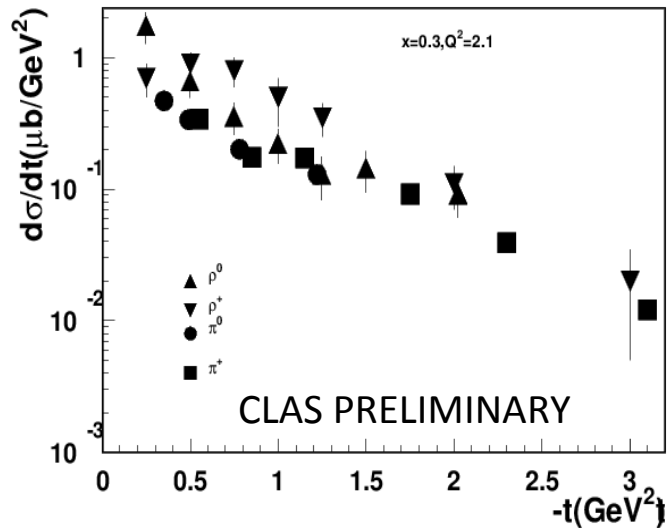
- Fraction of exclusive pairs could be separated
- Most of the pion pairs comes from SIDIS VM decays
 - those are mostly SIDIS VM

Exclusive π/ρ production at large t



Pions from rho decays may require special treatment for understanding of certain observables

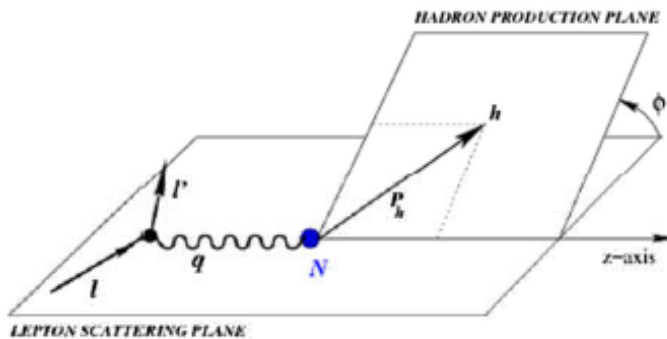
Beam Spin Asymmetry:



SIDIS Pion Beam Spin Asymmetries with CLAS12 at 10.6 GeV based on the DNP data

Stefan Diehl

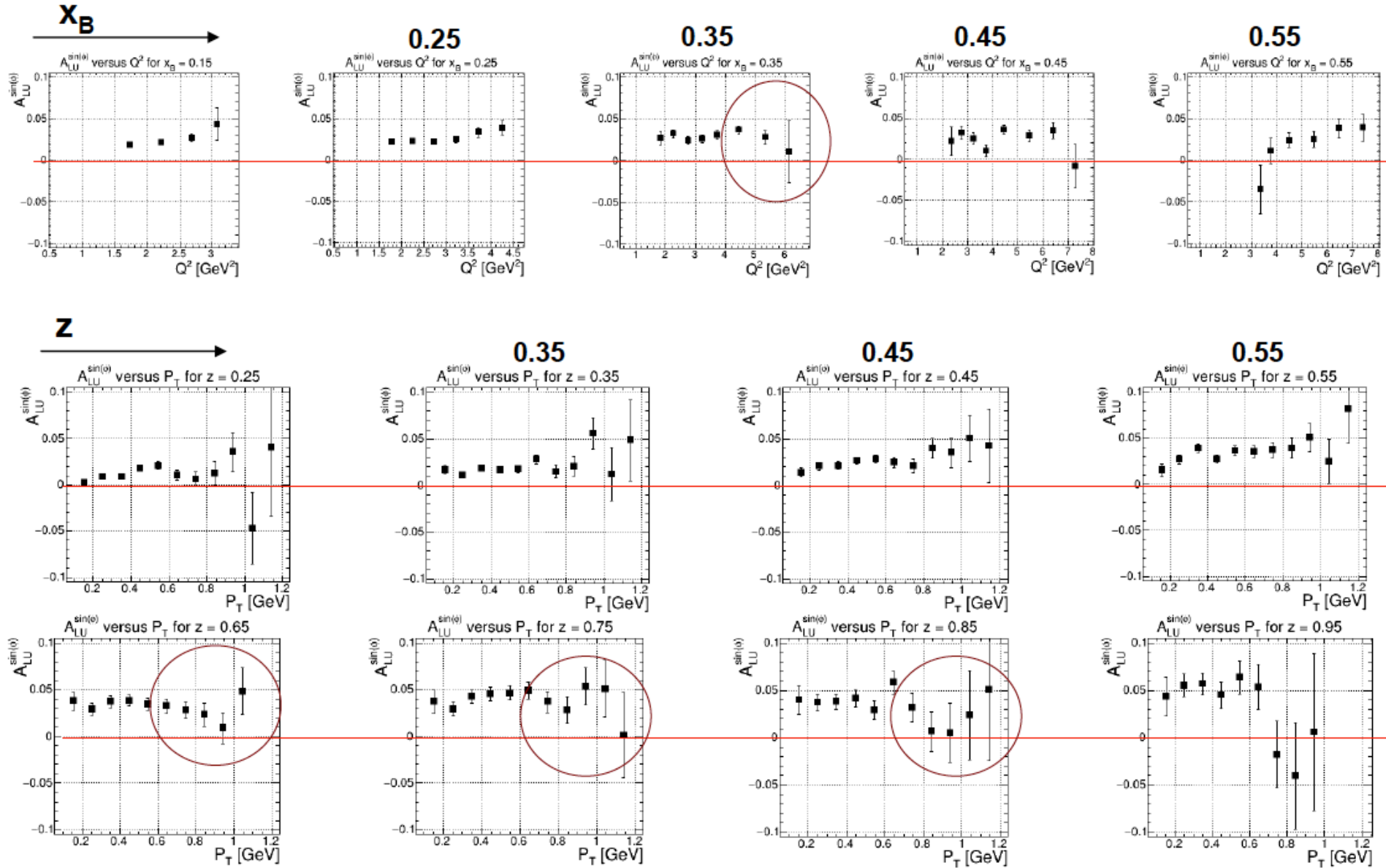
Justus Liebig University Giessen
University of Connecticut

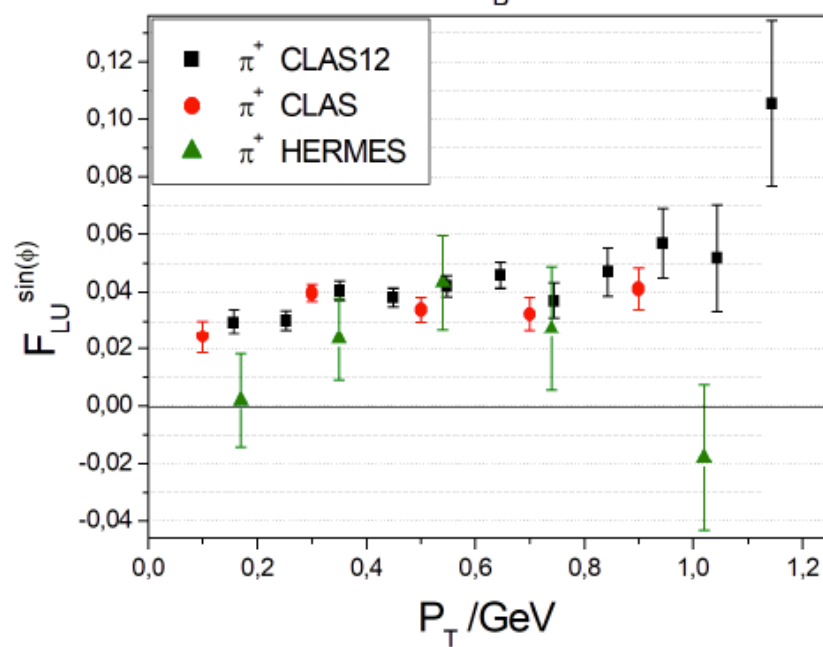
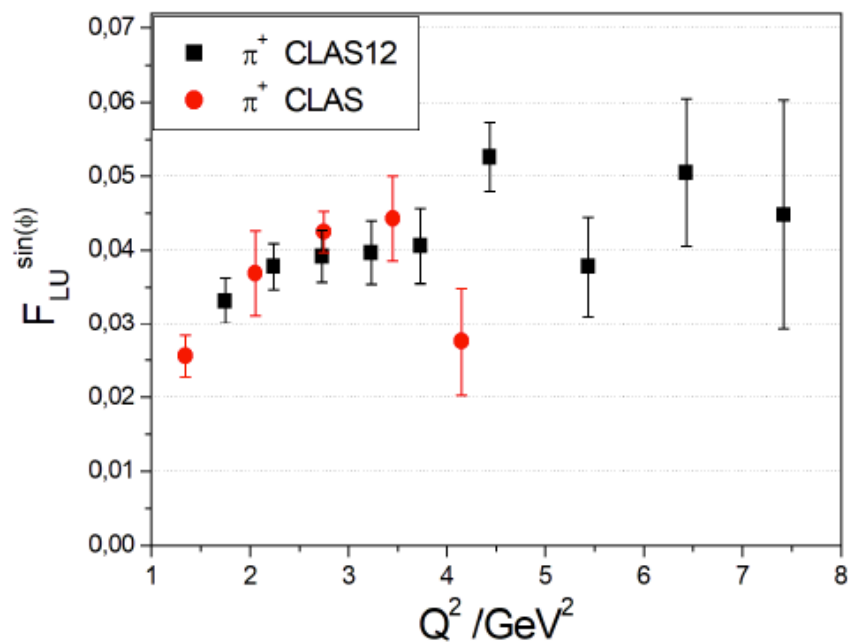
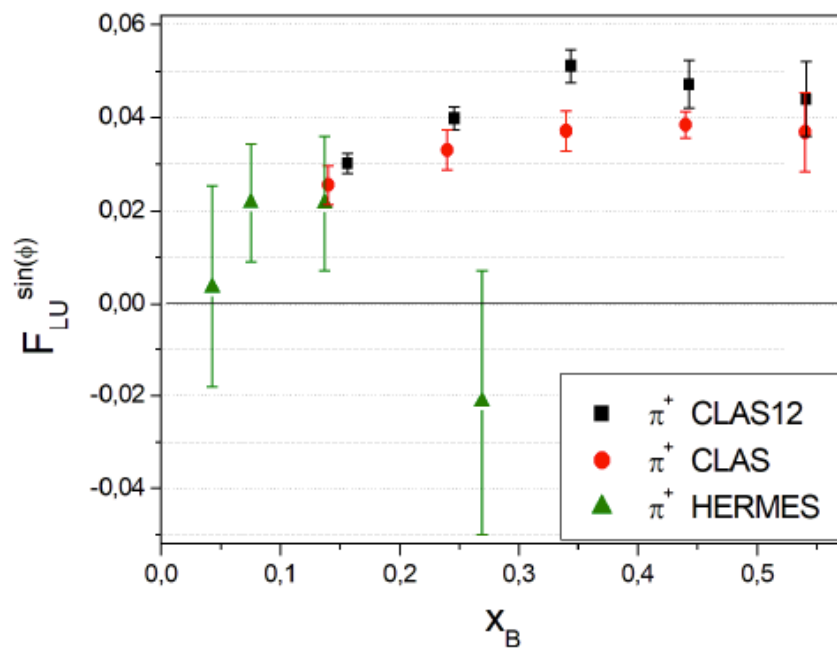
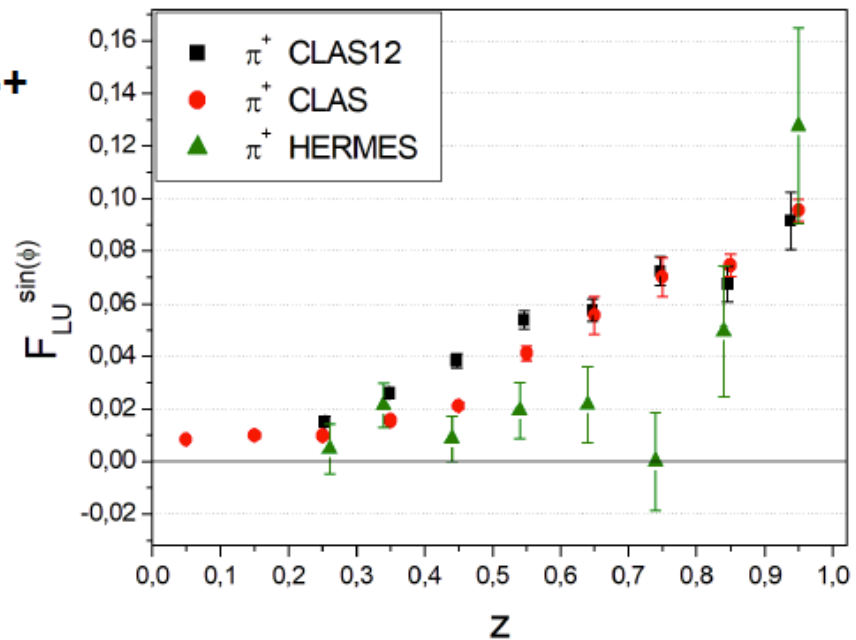


$$d\sigma = d\sigma_0 (1 + A_{UU}^{\cos\phi} \cos\phi + A_{UU}^{\cos 2\phi} \cos 2\phi + \lambda_e A_{LU}^{\sin\phi} \sin\phi)$$

$$F_{LU}^{\sin\phi} = \frac{2M}{Q} C \left(-\frac{\hat{\mathbf{h}} \cdot \mathbf{k}_T}{M_h} \left(\overset{\text{twist-3 pdf}}{x \overset{\text{Collins FF}}{e} \overset{\text{unpolarized dist. function}}{H_1^\perp}} + \frac{M_h}{M} \overset{\text{unpolarized dist. function}}{f_1} \frac{\overset{\text{twist-3 FF}}{\tilde{G}^\perp}}{z} \right) + \frac{\hat{\mathbf{h}} \cdot \mathbf{p}_T}{M} \left(x \overset{\text{twist-3 t-odd dist. function}}{g^\perp} \overset{\text{twist-3 t-odd dist. function}}{D_1} + \frac{M_h}{M} \overset{\text{Boer-Mulders}}{h_1^\perp} \frac{\overset{\text{twist-3 FF}}{\tilde{E}}}{z} \right) \right)$$

Towards multi-dimensional analysis

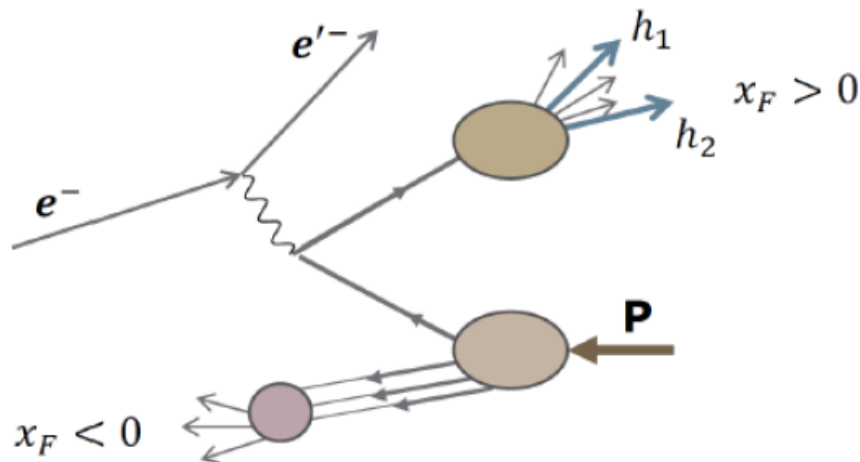


π^+ 

Di-hadron beam spin asymmetry with CLAS data

Marco Mirazita

INFN – Laboratori Nazionali di Frascati



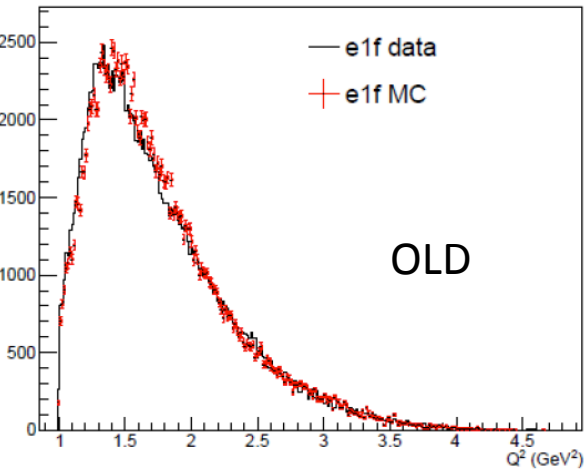
SIDIS di-hadron BSA on e1f data
to access higher twist PDF $e(x)$

Connected to nucleon scalar charge
and transverse force on the struck quark

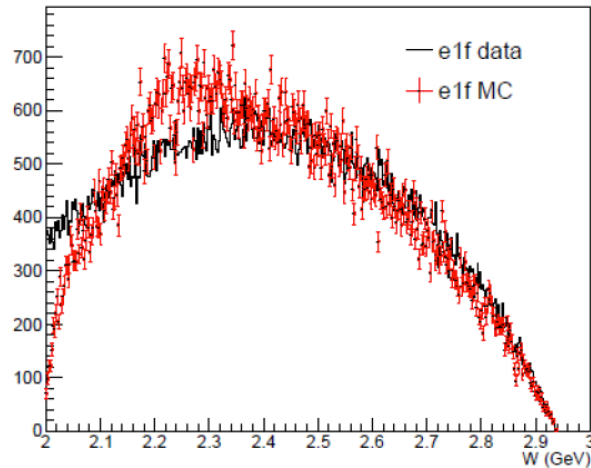
- **Analysis under responsibility of S. Pisano (LNF)**
 - analysis completed in 2014
 - preliminary results presented at Conferences in 2013-14
 - theoretical interpretation of the data by A. Courtoy

DATA vs MC Kinematic Distributions

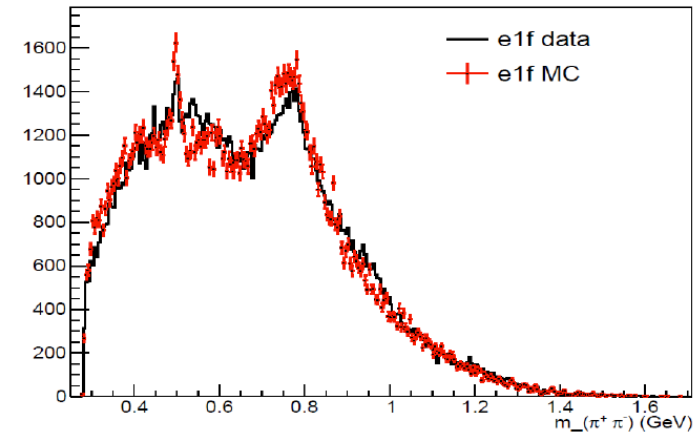
Q^2 distribution



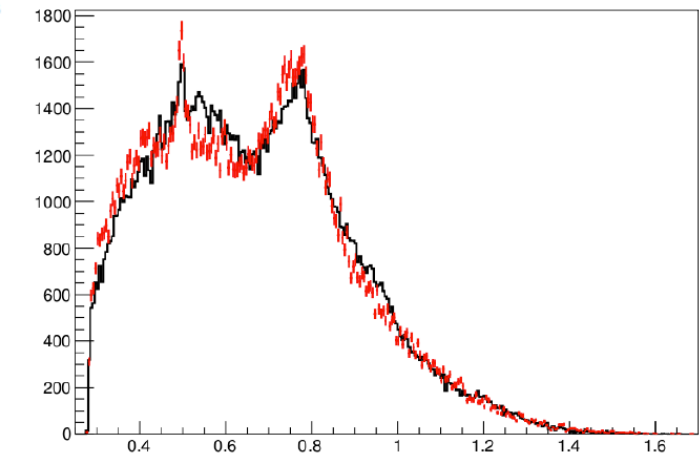
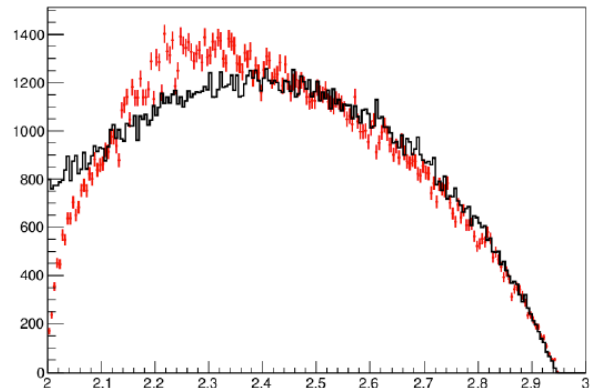
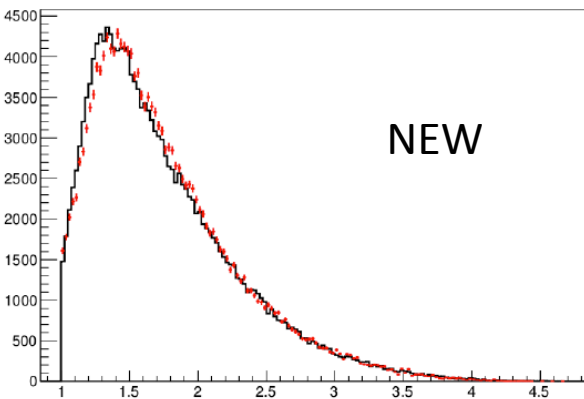
W distribution



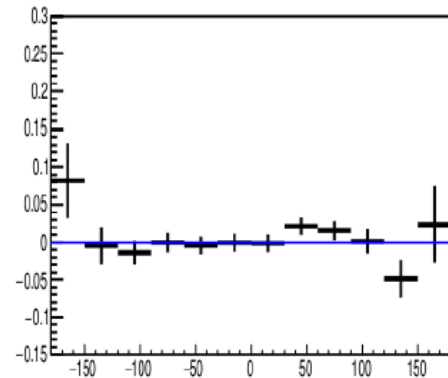
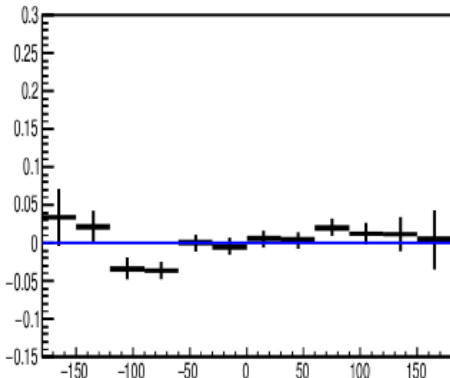
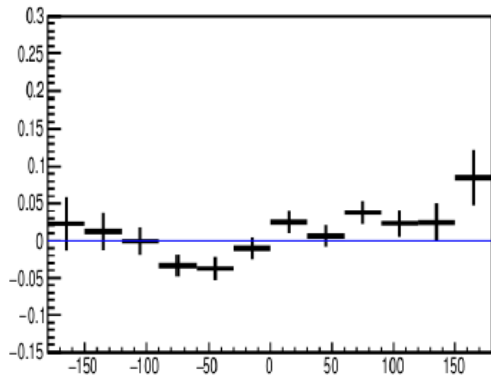
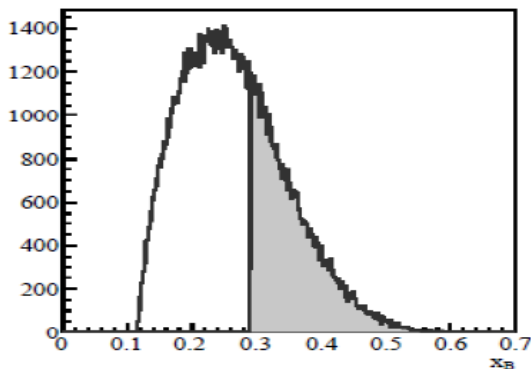
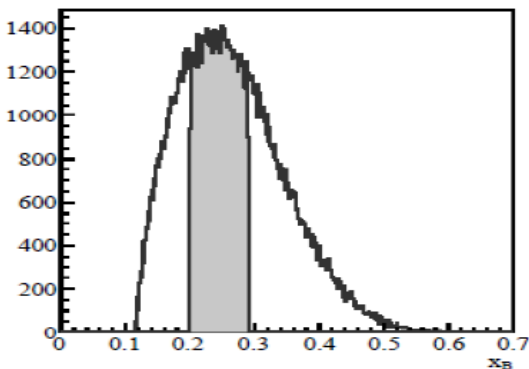
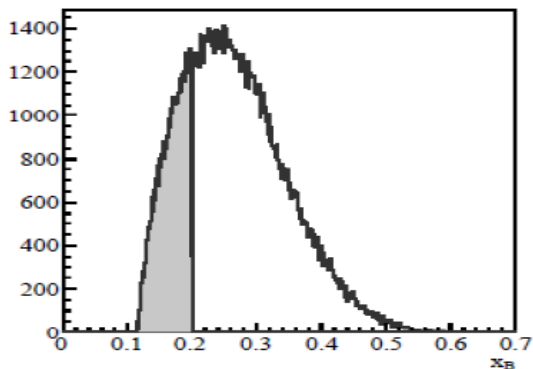
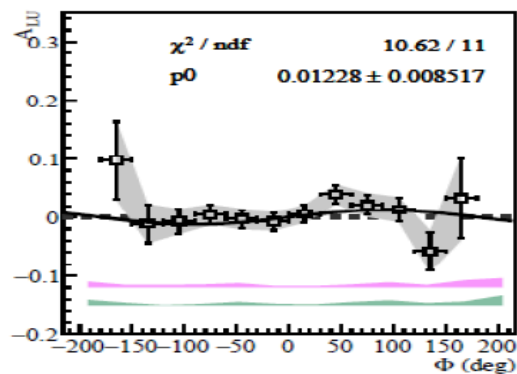
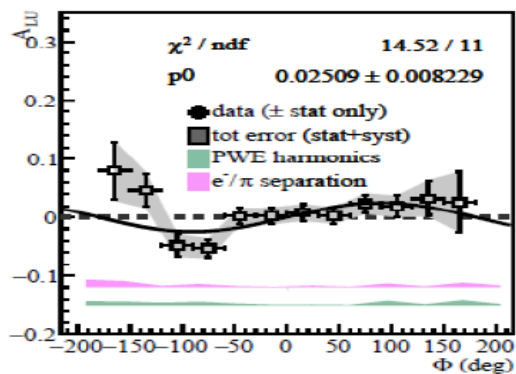
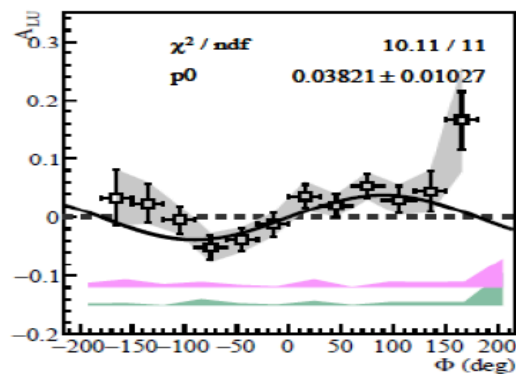
invariant mass of the $\pi^+ \pi^-$ system



NEW

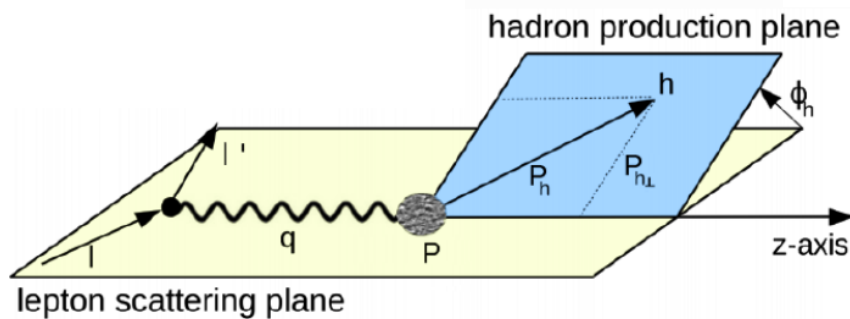


BSA vs Bjorken-x



Neutral Pion DIS Multiplicity with CLAS12 Data

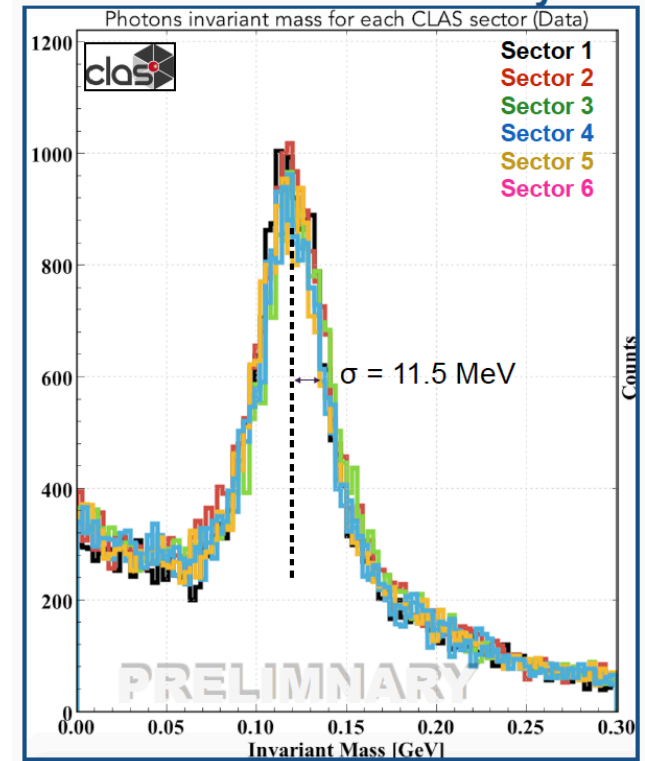
Giovanni Angelini

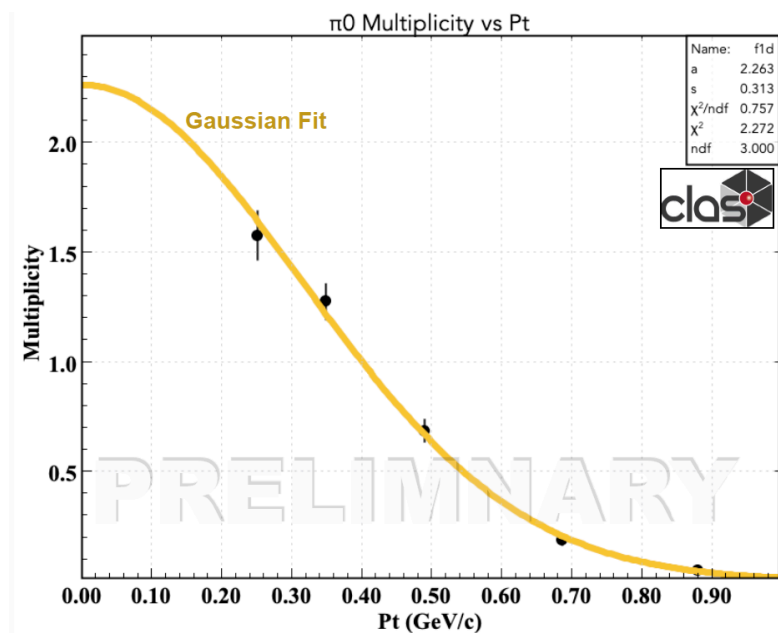
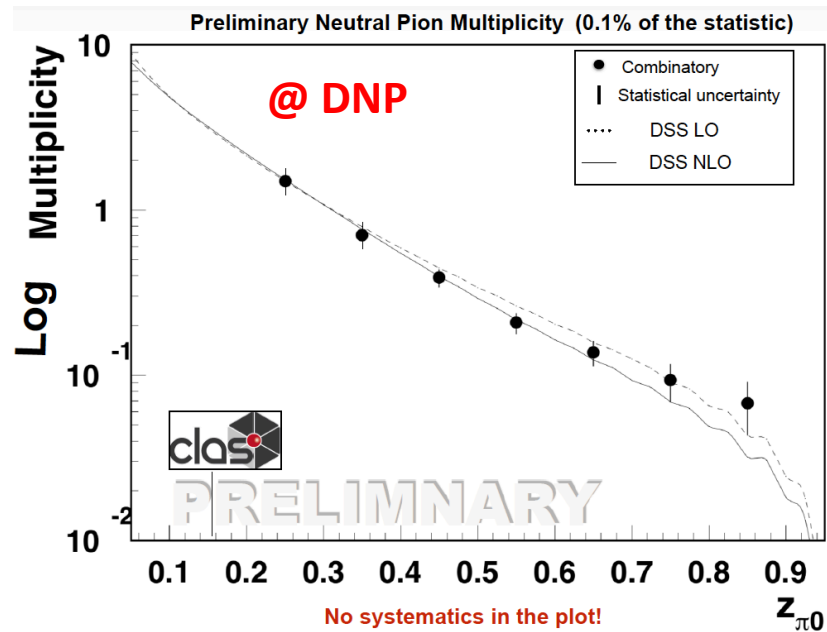
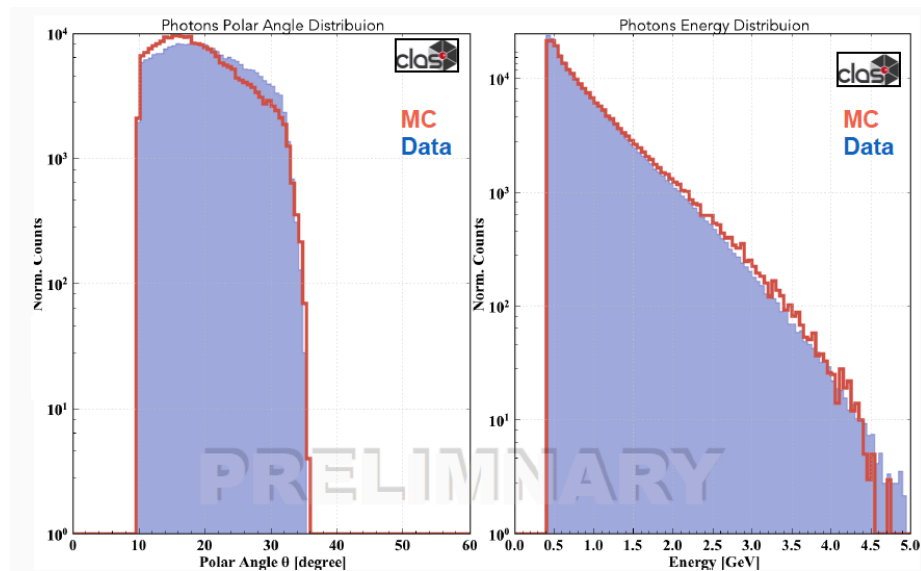
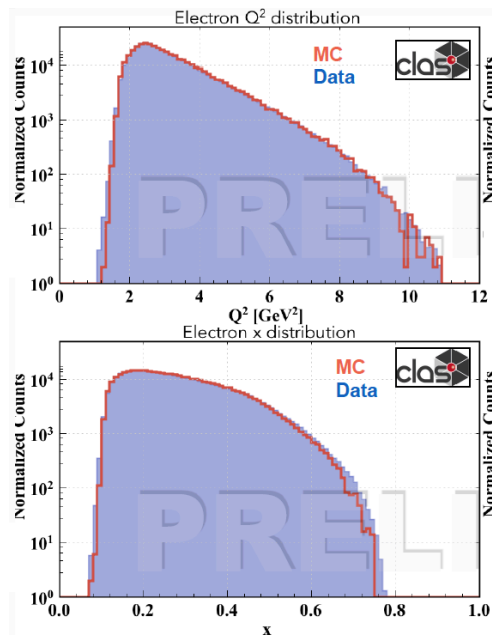


Multiplicity:

$$m^h(x, z, dP_{hT}^2, Q^2) = \frac{d\sigma_{SIDIS}^h / dx dz dP_{hT}^2 dQ^2}{d\sigma_{DIS} / dx dQ^2}$$

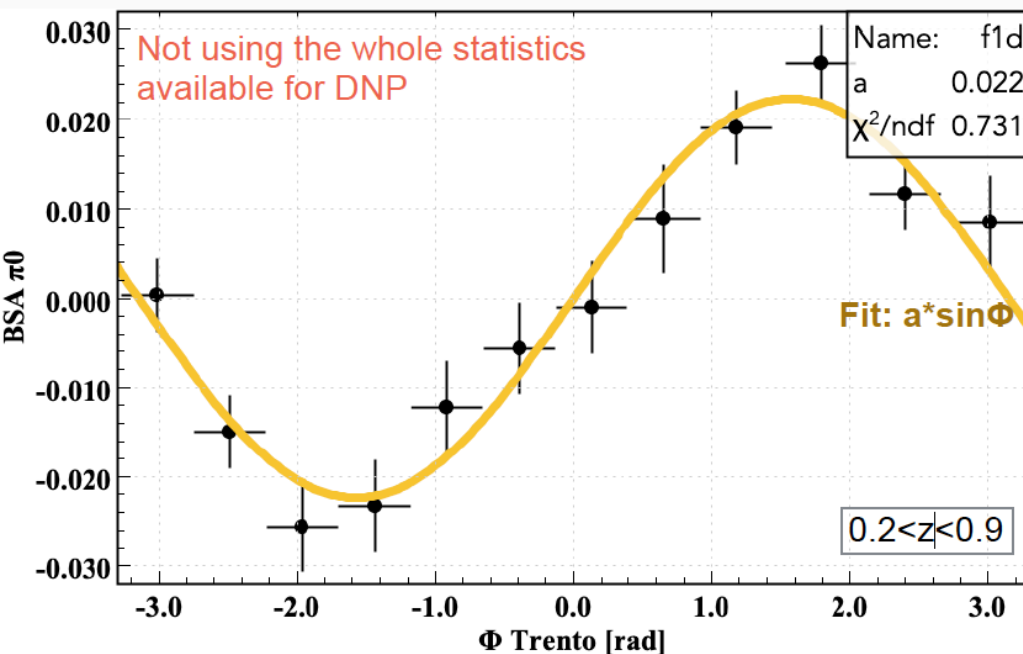
Cal. Sector Uniformity



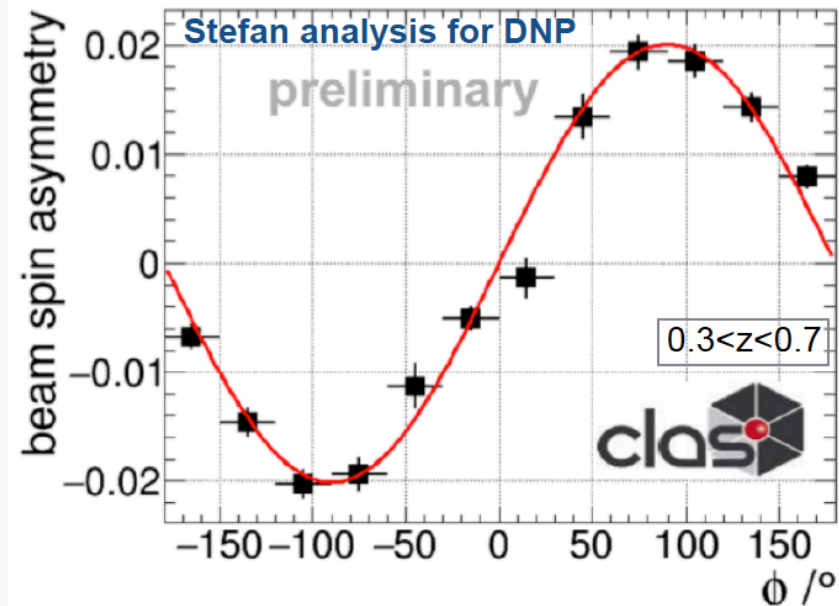


Beam Single Spin Asymmetry

BSA can be extracted from the same sample



$$BSA^{\pi^0} = \frac{1}{P} \frac{\overrightarrow{\pi^0} - \overleftarrow{\pi^0}}{\pi_{Total}^0}$$



MC, acceptances studies, fiducial cuts, etc. can be cross checked and used in both analysis
Independent cross checking with UCONN analysis

10:30 - 12:10

Deep Processes Working Group - II

<https://bluejeans.com/551610659>

Convener: Mr. Marco Contalbrigo (INFN Ferrara)

Location: F113

10:30 **π^0/η impact on chiral-odd GPDs and CLAS12 analysis plans 20'**

Speaker: Andrey Kim (UCONN)

Material: **Slides** 

10:50 **DVCS study with CLAS12 20'**

Speaker: Guillaume CHRISTIAENS (SACLAY)

Material: **Slides** 

11:10 **TCS simulation studies 20'**

Speaker: Mr. Pierre Chatagnon (ORSAY)

Material: **Slides** 

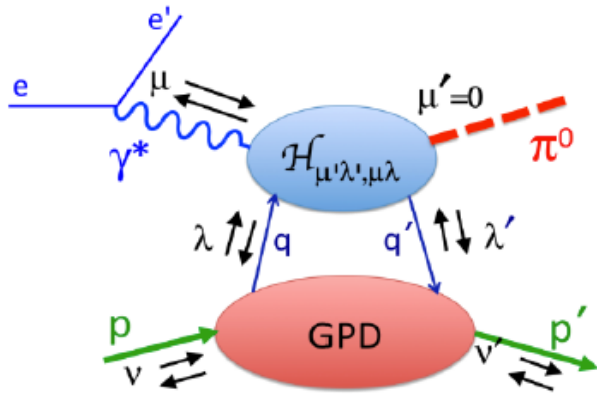
11:30 **Photo production of a meson-photon pair at large invariant mass 20'**

Speaker: Francois-Xavier Girod (UConn)

Material: **Slides** 

11:50 **MC plans for Exclusive Processes 20'**

Speaker: Mr. Marco Contalbrigo (INFN Ferrara)



		Quark polarization		
		U	L	T
Nucleon polarization	U	H		$\bar{E}_T$
	L		$\tilde{H}$	
	T	E		$H_T, \tilde{H}_T$

GPDs parametrization:

H_T

tensor charge: T.Ledwig, A.Silva, H.C. Kim

$$\int dx H_T(x, \xi, t)$$

transversity PDF: M.Anselmino

$$H_T(x, \xi = 0, t = 0) = h_1$$

$$\bar{E}_T = 2\tilde{H}_T + E_T$$

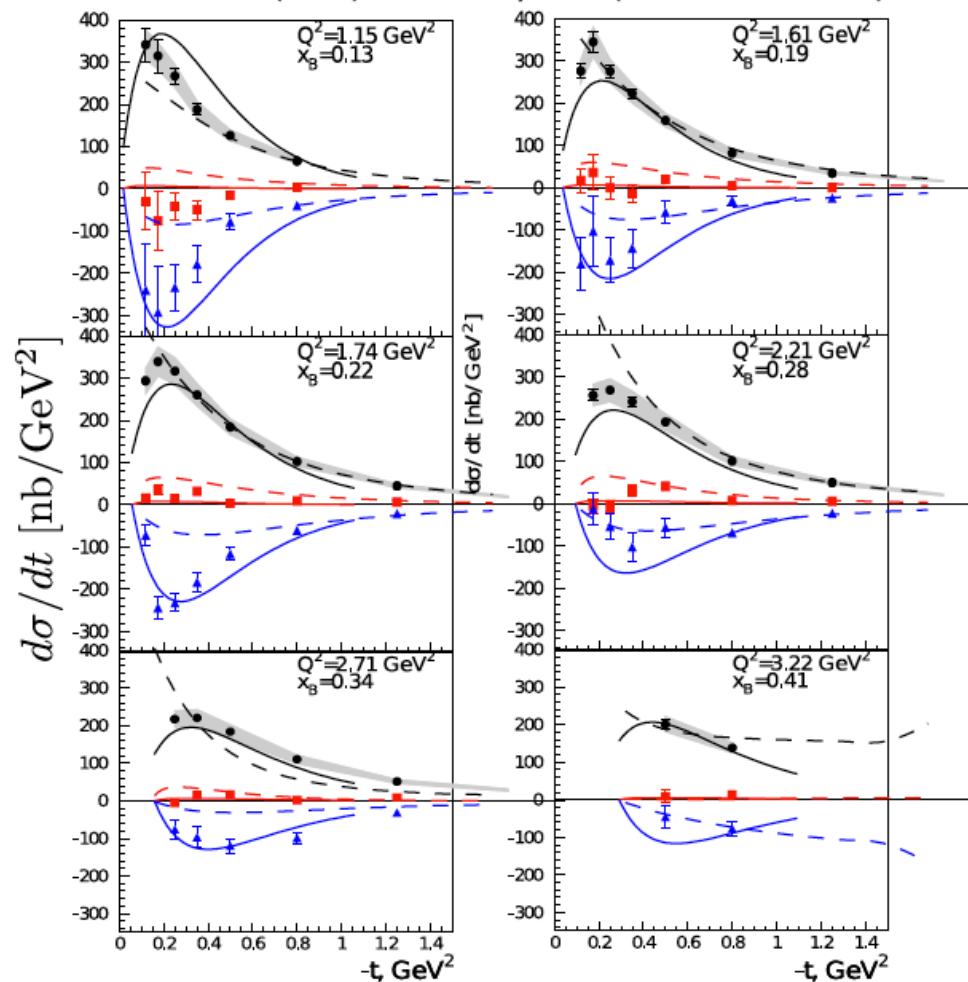
Lattice QCD: M.Gockeler

$\bar{E}_T$ moments

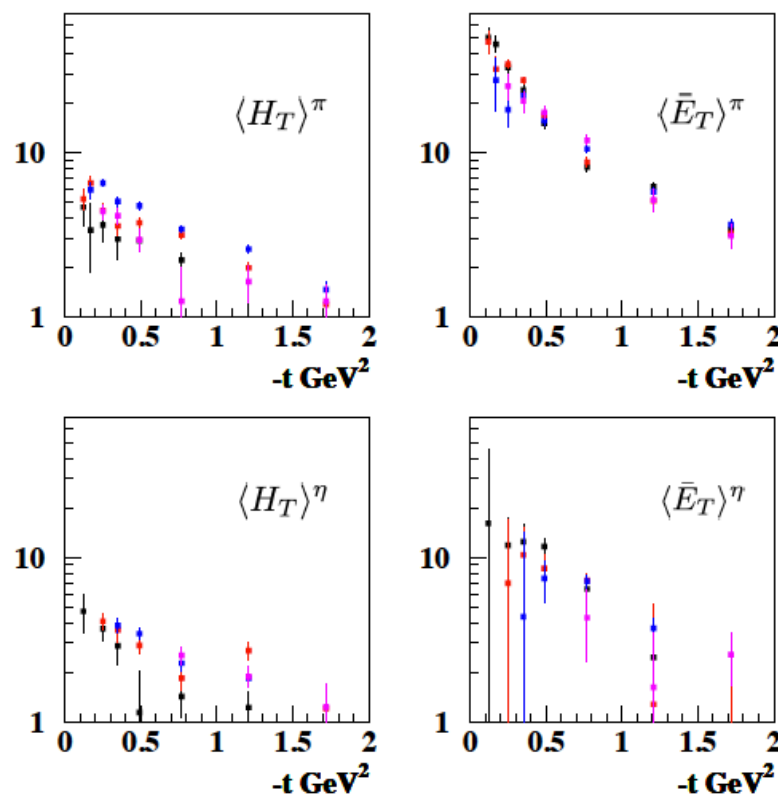
CLAS measurements of pseudoscalar meson production

π^0 measurements

PRL109:112001 (2012) I. Bedlinskiy et al. (CLAS collaboration)

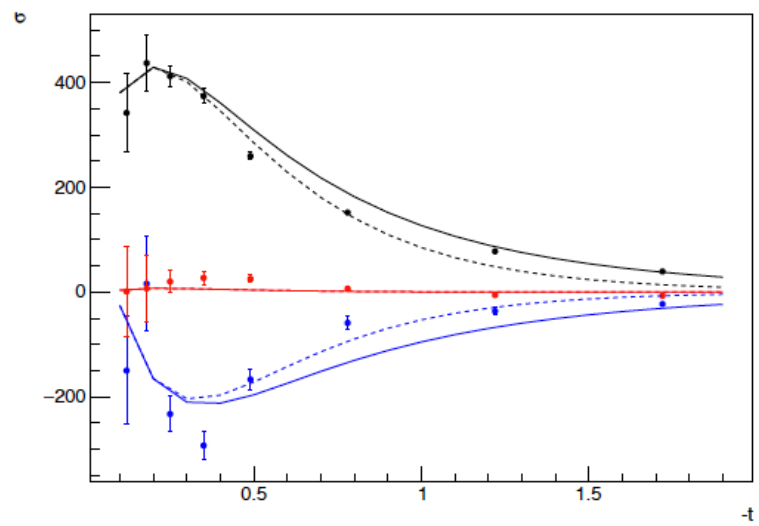


Generalized Form Factors



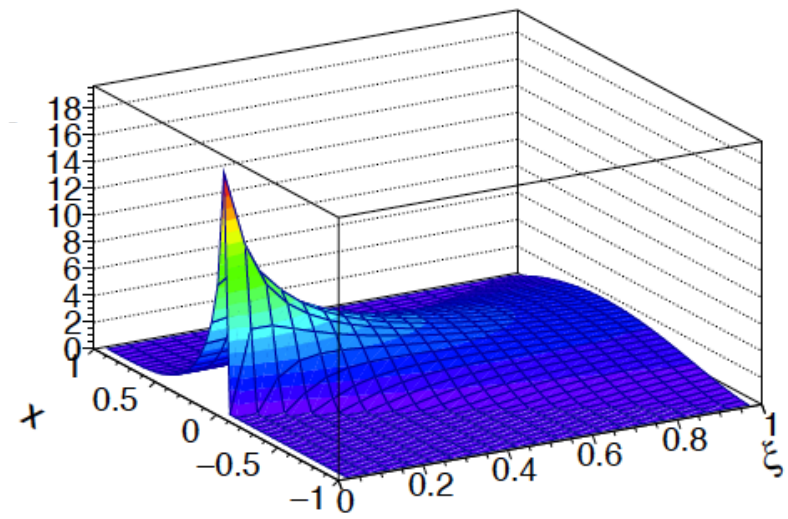
Now: HEPGen++ with pre-calculated grid of sub-process amplitudes

Structure functions (Q2,xB) = 1.8700 0.2710

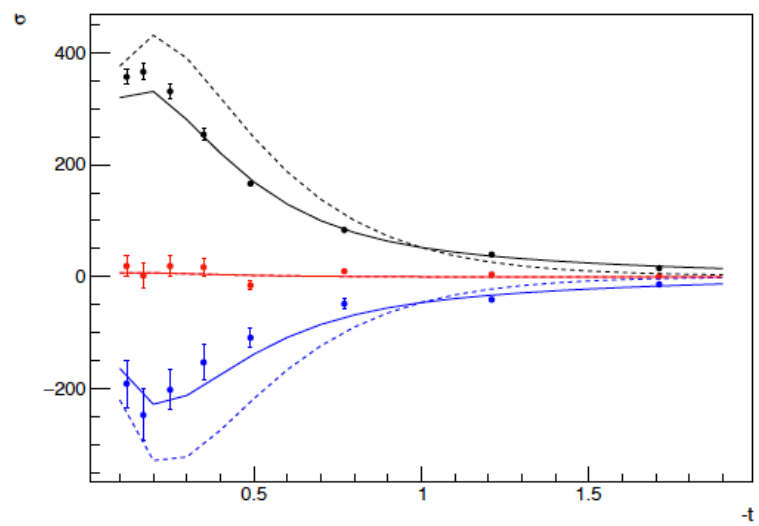


u quark

$$\bar{E}_{T,d}(x,\xi,t=-0.1(\text{GeV}/c)^2)$$

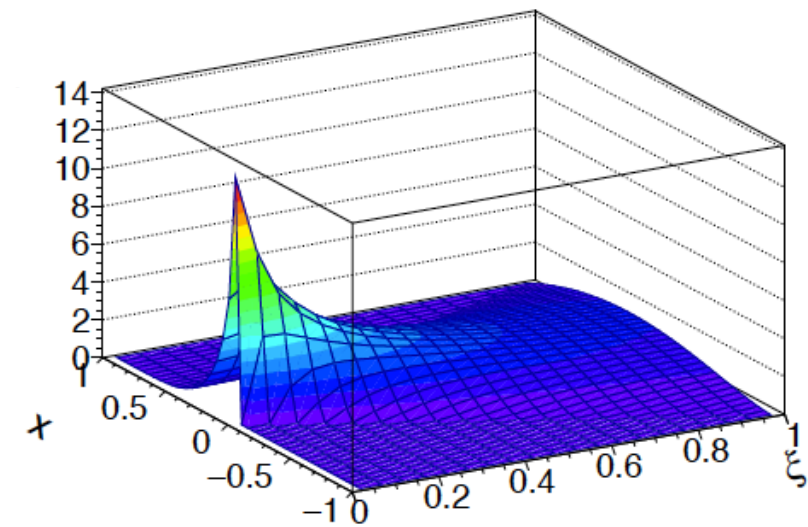


Structure functions (Q2,xB) = 1.3800 0.1691



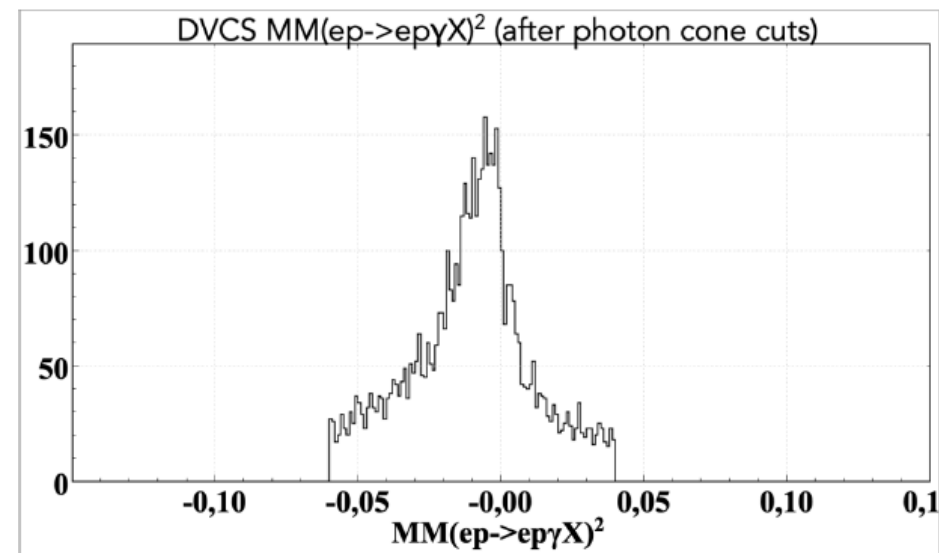
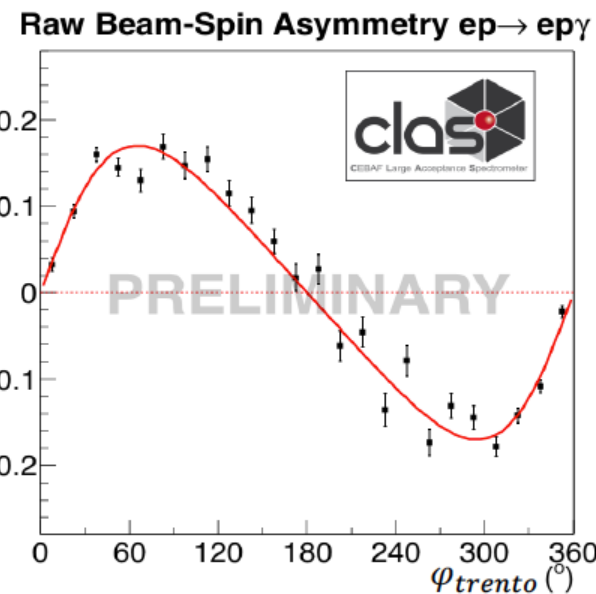
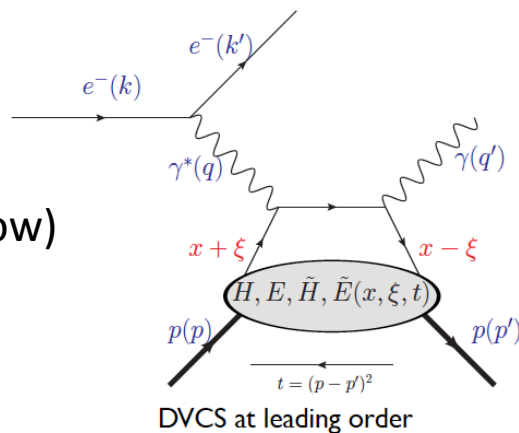
d quark

$$\bar{E}_{T,u}(x,\xi,t=-0.1(\text{GeV}/c)^2)$$

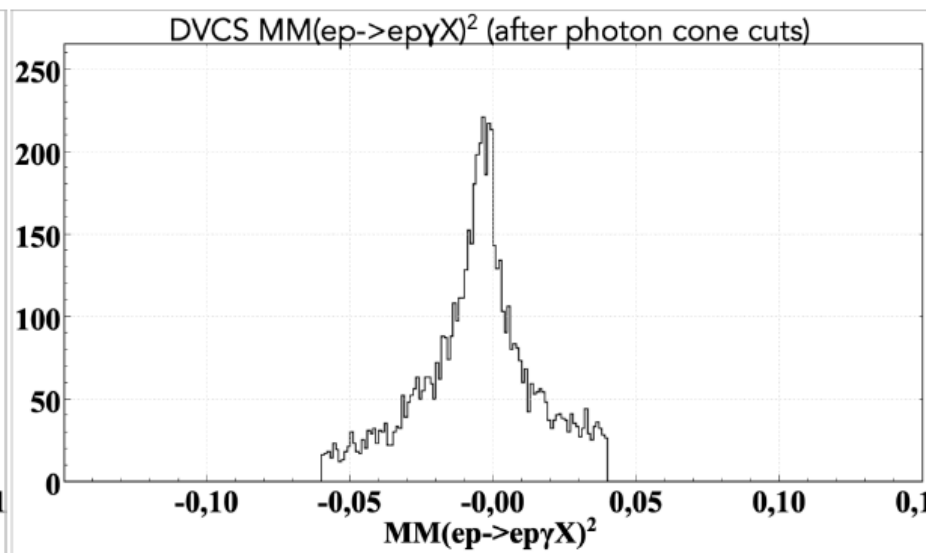


Deeply Virtual Compton Scattering at 10.6 GeV with CLAS12 at Jefferson Lab

Guillaume CHRISTIAENS
(CEA Saclay, University of Glasgow)



Old Cooking version 5b.6.1

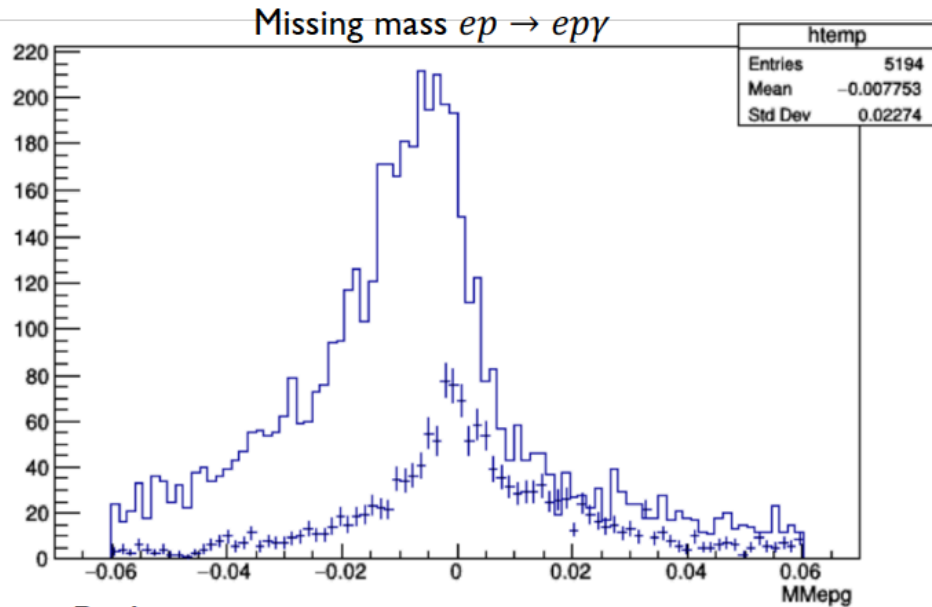


New Cooking version 5b.7.8

π^0 contamination

Method 1

From MC simulation:



Preliminary pion contamination
(line for total signal
and crosses for pion background)

Method 2

DATA driven:

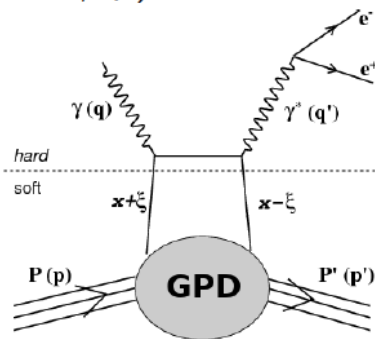
- Identify π^0 in the data
- Simulate decay of these pions
- The pions with only one photon detected is background for DVCS

Timelike Compton Scattering with CLAS12 at Jefferson Lab

Pierre Chatagnon

Institut de Physique Nucleaire d'Orsay

TCS ($\gamma p \rightarrow \gamma^* p$)

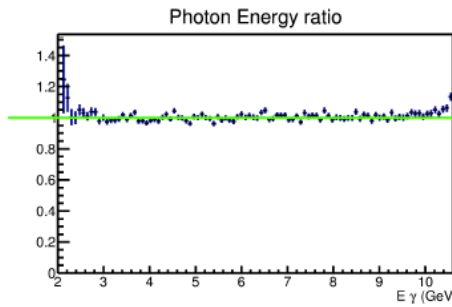
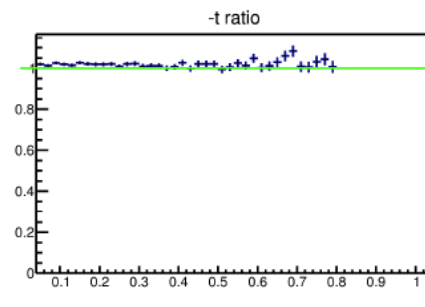
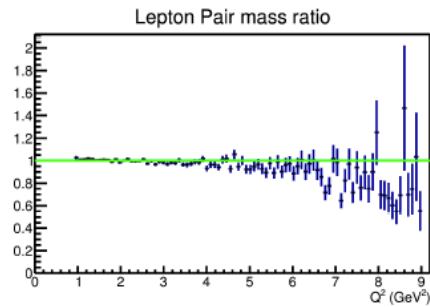
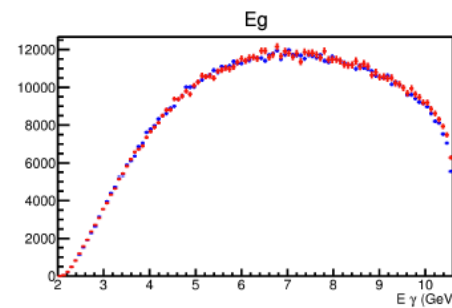
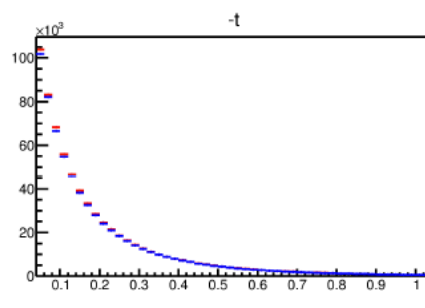
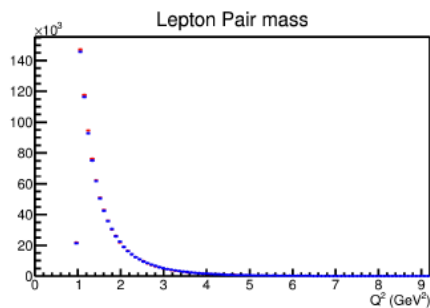


$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} \approx [\cos(\phi)] \frac{1 + \cos^2(\theta)}{\sin(\theta)} \text{Re } \tilde{M}^{--} + \dots$$

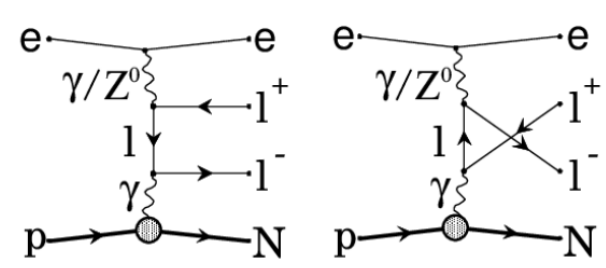
$$\tilde{M}^{--} = \frac{2\sqrt{t_0 - t}}{M} \frac{1 - \xi}{1 + \xi} \left[F_1 \mathcal{H} - \xi(F_1 + F_2) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2 \mathcal{E} \right]$$

GRAPE

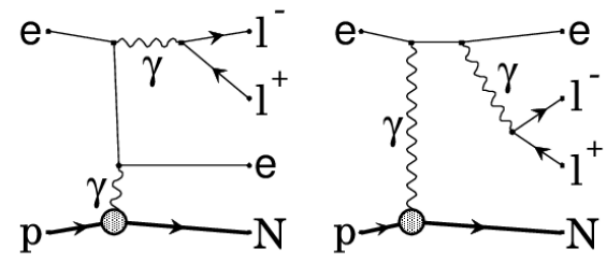
Rafo's Gene



Study of Backgrounds from MC

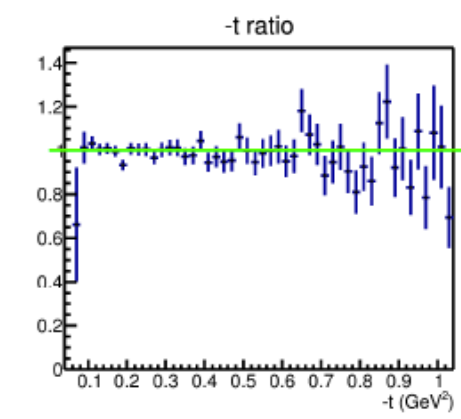
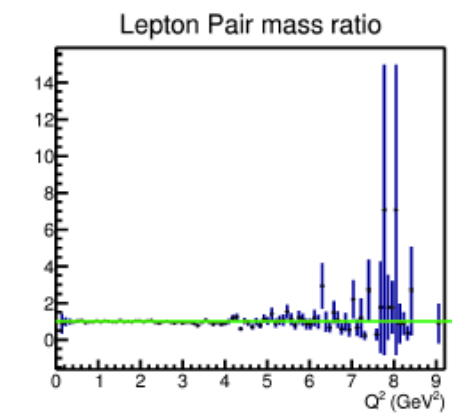
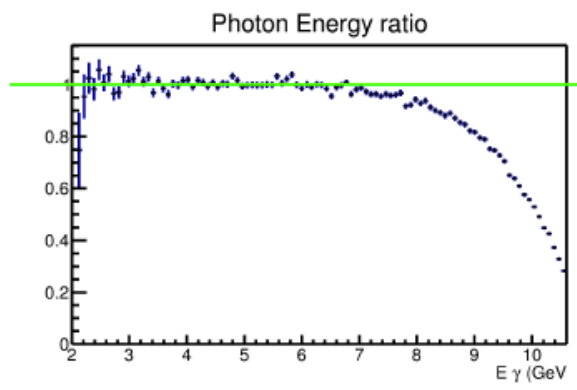
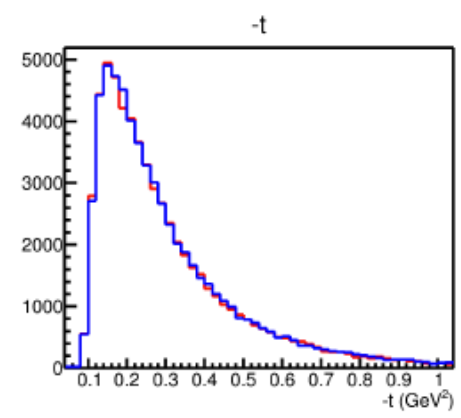
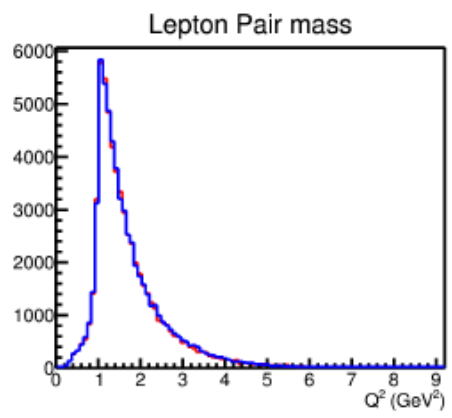
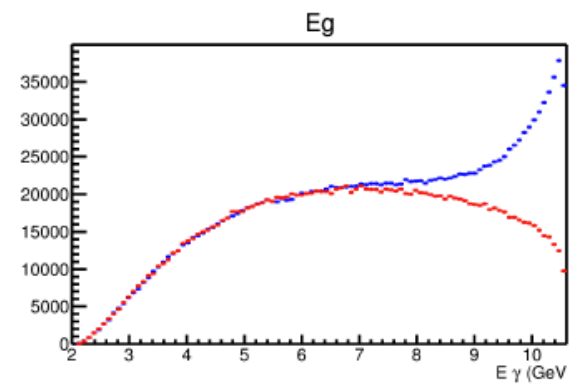


(a) Bethe-Heitler type diagrams



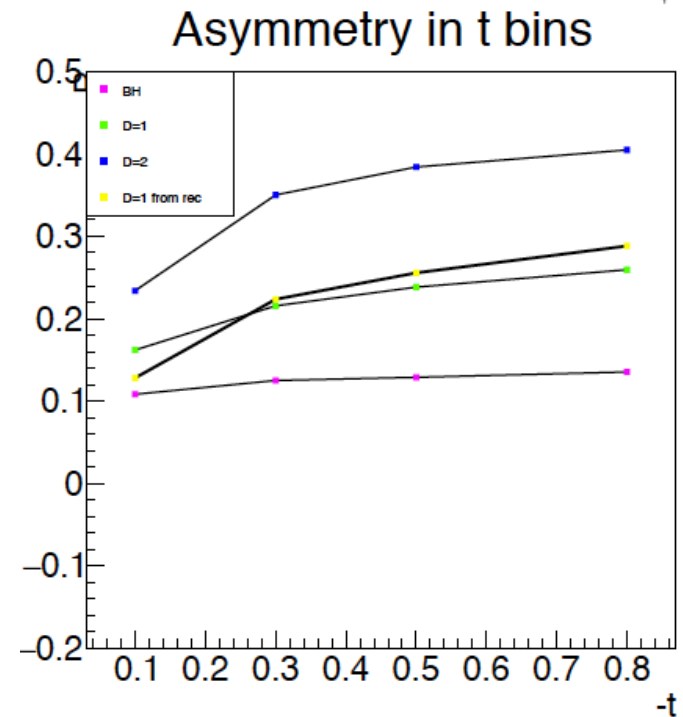
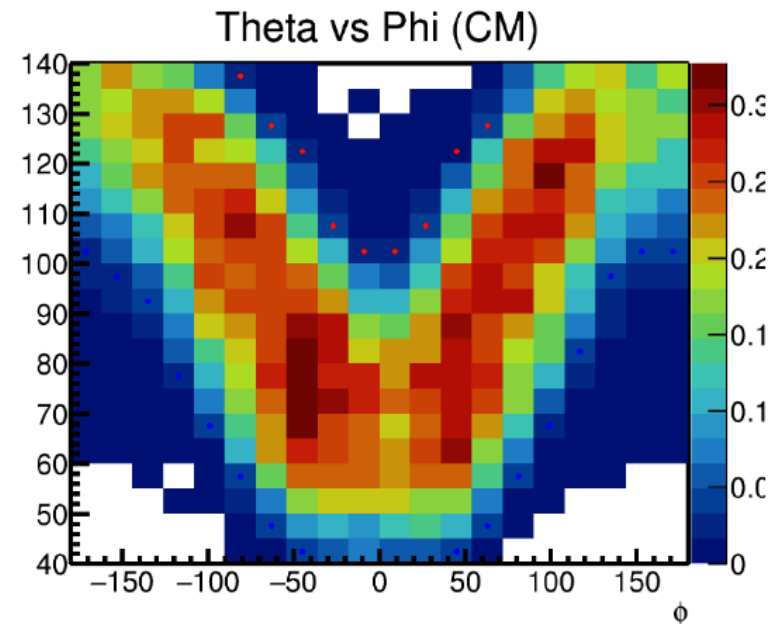
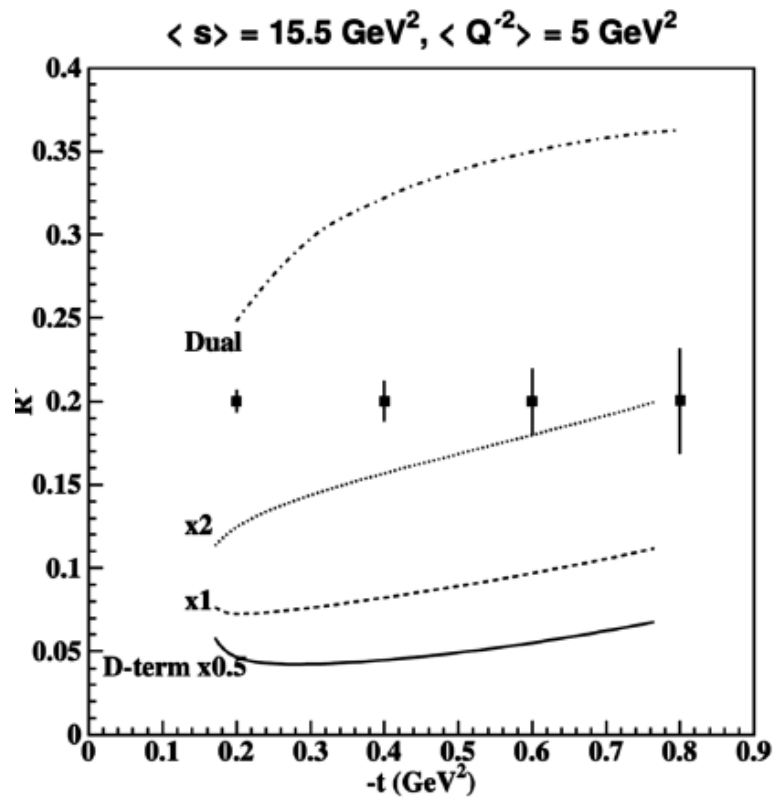
(b) QED-Compton type diagrams

Direct BH **Int+QED**



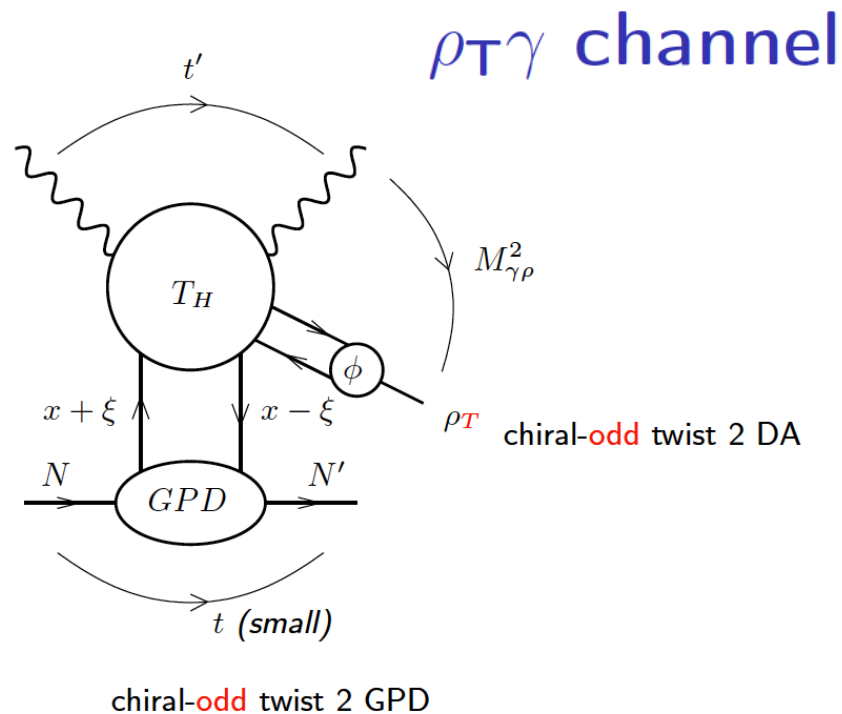
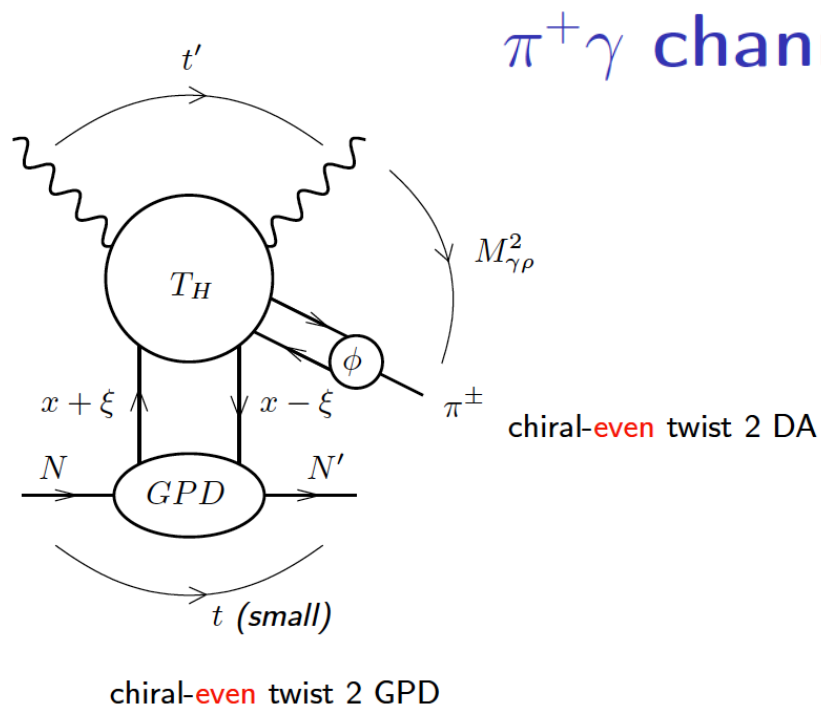
Experimental cross section ratio

$$R' = \frac{\sum_{\phi} \cos(\phi) Y_{\phi}}{\sum_{\phi} Y_{\phi}} \quad Y_{\phi} = \sum_{\theta} \frac{L}{L_0} N_{\theta}^{\phi} \frac{1}{A_{\theta}^{\phi}}$$



Photoproduction of a meson-photon pair at large invariant mass

F.-X. Girod
Jefferson Laboratory / UConn

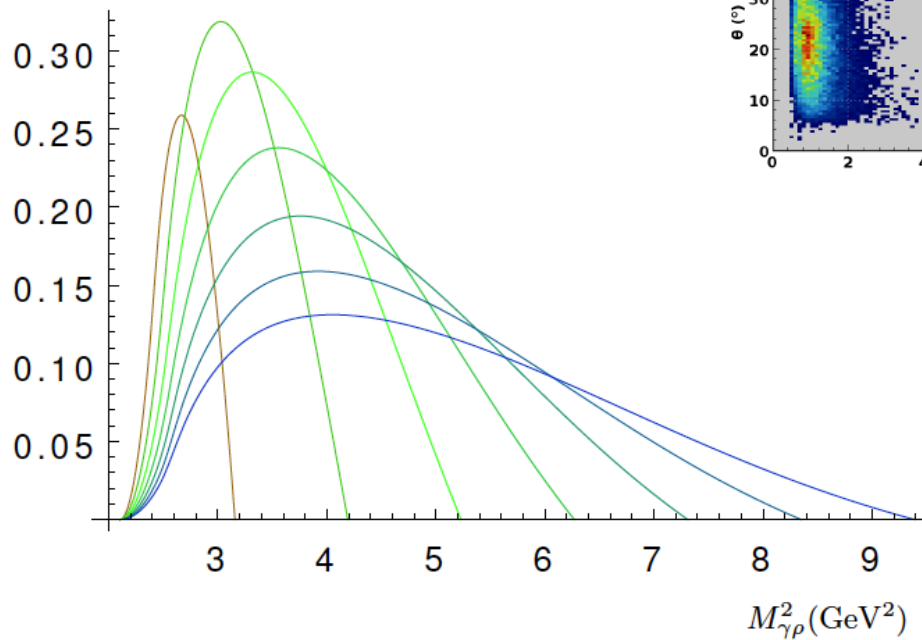


- QCD collinear factorization established; firm grounds
- model calculations available
- large statistics predicted for CLAS12

Ref.: JHEP 1702 (2017)
(arXiv:1609:03830)

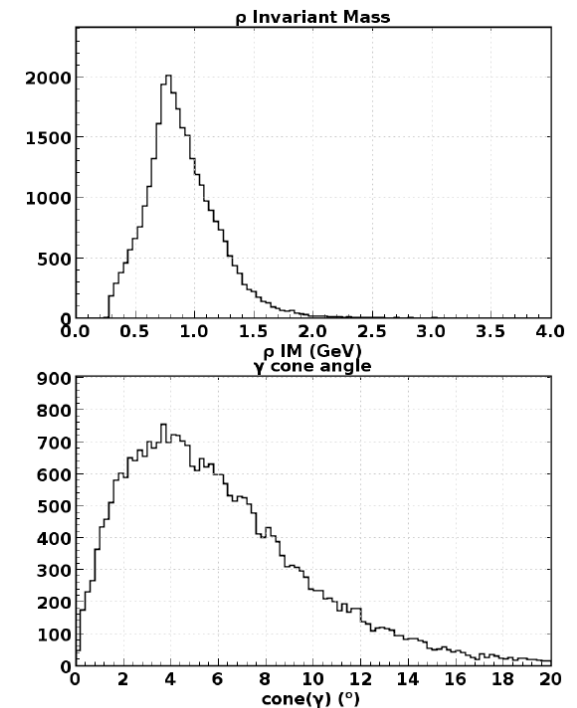
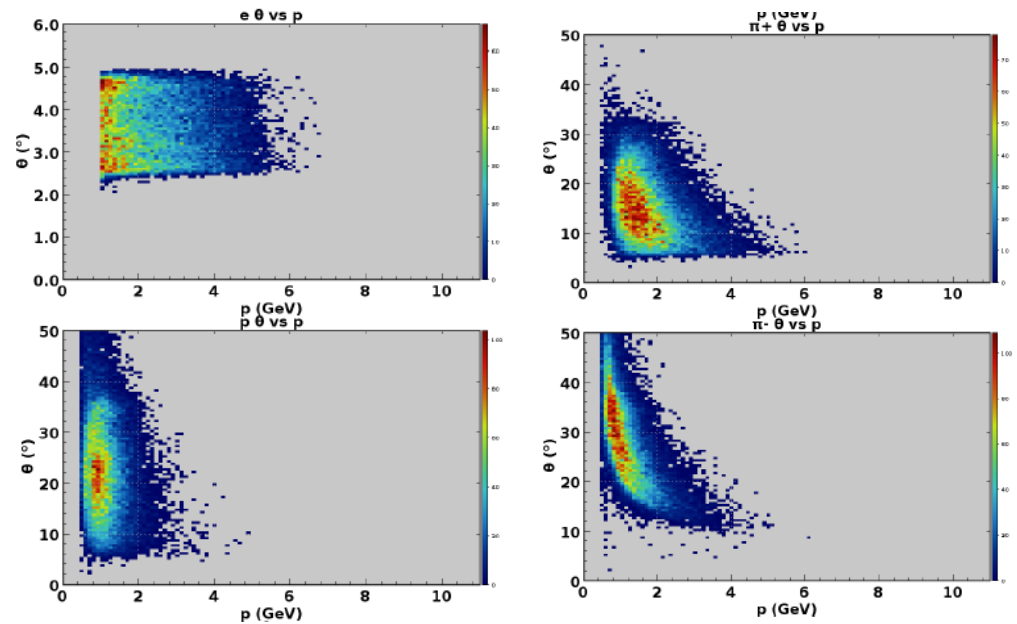
$\rho\gamma$ channel

$$\frac{d\sigma_{\text{odd}}}{dM_{\gamma\rho}^2} \text{ (pb} \cdot \text{GeV}^{-2}\text{)}$$



proton target, “valence” scenario

$S_{\gamma N}$ vary in the set 8, 10, 12, 14, 16, 18, 20 GeV^2



	Reaction	Energy	Statistics (10^6)	Generator	Configuration	Disk (Tb)
Giovanni/ Stefan	SIDIS h	10.6	> 500	CLASDIS no rad	?	1.4
		10.6	> 500	CLASDIS + rad	?	< 4
	SIDIS di-h	10.6	> 500	?	?	

	Reaction	Energy	Statistics (10^6)	Generator	Configuration	Disk (Tb)
Brandon	Excl. ϕ	10.6	50	PhiGen	Outbending	
Josh	DVCS	10.6	10	DVCS	In/Out	
	Excl. π^0	10.6	10	Pi0Gen	In/Out	
	DVCS	10.6	10	DVCS	In/Out, no FMT	
	Excl. π^0	10.6	10	Pi0Gen	In/Out, no FMT	
	DVCS	7.5	10	DVCS	Out, no FMT	
	Excl. π^0	7.5	10	Pi0Gen	Out, no FMT	
	DVCS	6.5	10	DVCS	In/Out, no FMT	
	Excl. π^0	6.5	10	Pi0Gen	In/Out, no FMT	

