

Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, 14th November 2019

Ad Hoc Reviews

Analysis	Data	Lead 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	1 nd round done on Aug 19
Exploring the structure of the proton via semi-inclusive pion electro-production	e1f	N. Harrison K. Joo	2 nd round done on Jan 19

Analysis Reviews

Analysis	Data	Author	In progress
First Observations of Beam Spin Asymmetries for K+	e1f	D. Riser	2 nd round done on Jul 19
Measurement of the spin structure g _{1p} of the proton and its momentum at low Q ²	eg4	X. Zheng	2 nd round done on Nov 19
24Di-hadron beam spin asymmetry in SIDIS electro production	eg1-dvcs	M. Mirazita	Going to restart soon
Beam asymmetries in exclusive π^+ electro production for W > 1.7 GeV from e16	e16	P. Bosted K. Park	Extended scope
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	2nd round done on Sep 19
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

DNP 2019

Fall Meeting of the Division of Nuclear Physics of the American Physical Society

T. Hayward	Charged di-hadron beam-spin asymmetries from CLAS12
S. Diehl	SIDIS Single Pion Beam Spin Asymmetry Measurements with CLAS12
C. Dilks	Dihadron Beam Spin Assymetries and Helicity-Dependent Fragmentation in SIDIS at CLAS12
H. Avakian	Hadronization of quarks and correlated di-hadron production in DIS
G. Christiaens	Proton Deeply Virtual Compton Scattering at 10.6 GeV with CLAS12 at Jefferson Lab
A. Kim	Deeply Virtual Exclusive pi0 Electro-production Measurements with CLAS12 at Jefferson Lab
B. Clary	Exclusive Phi Meson Electro-production for CLAS12
J. Artem Tan	Deeply Virtual Compton Scattering with CLAS12 at Multi-Energy Polarized Electron Beam
A. Biselli	Coherent Deuteron Deeply Virtual Compton Scattering with CLAS12
K. Price	Deeply Virtual Compton Scattering on the Neutron
C. Fogler	Investigating the Origin of the EMC Effect
S. Diehl	TDA Measurements based on hard exclusive pion electroproduction with CLAS at JLAB
M. Hattaway	3D Partonic Structure of Nucleon and Light Nuclei
D. Payette	Tracking Low-momentum Protons in a Radial Time Projection Chamber

CLAS Collaboration Meeting

from Tuesday, 12 November 2019 at **08:30** to Friday, 15 November 2019
at **Jefferson Lab**

12000 Jefferson Ave, Newport News, VA 23606

08:30 **DPWG business 5'**

Speaker: Mr. Marco Contalbrigo (INFN Ferrara)

Material: [Slides](#) 

08:35 **BAND: status of analysis and calibration 20'**

Speaker: Efrain Segarra (MIT)

Material: [Slides](#) 

08:55 **Time-like Compton scattering with CLAS12 20'**

Speaker: Pierre Chatagnon (Orsay)

Material: [Slides](#) 


09:15 **Measurement of transition GPDs and baryon spectroscopy in non-diagonal DVCS 15'**

Speaker: Dr. Stefan Diehl (Justus Liebig University Giessen and University of Connecticut)

Material: [Slides](#) 

09:30 **Hadron momentum correction 20'**

Speakers: Francois-Xavier Girod (UConn), Dr. Harut Avagyan (Lab)

Material: [Slides](#) 

09:50 **Implementation of DVMP in PARTONS 20'**

Speaker: Mr. KEMAL TEZGIN (University of Connecticut)

Material: [Slides](#) 


10:30 **Exclusive phi: MC vs DATA comparison 10'**

Speaker: Brandon Clary (UCONN)

Material: [Slides](#) 

10:40 **BSA from Deeply virtual pi0 electroproduction measurements with CLAS12 20'**

Speaker: Andrey Kim (UCONN)

Material: [Slides](#) 

11:00 **SIDIS pi0 multiplicities 20'**

Speaker: Mr. Giovanni Angelini (George Washington University)

Material: [Slides](#) 

11:20 **Di-hadron beam spin asymmetries with CLAS6 20'**

Speaker: marco mirazita (infN laboratori nazionali di frascati)

Material: [Slides](#) 

11:40 **Simultaneous extraction of di-hadron beam spin asymmetry modulations 15'**

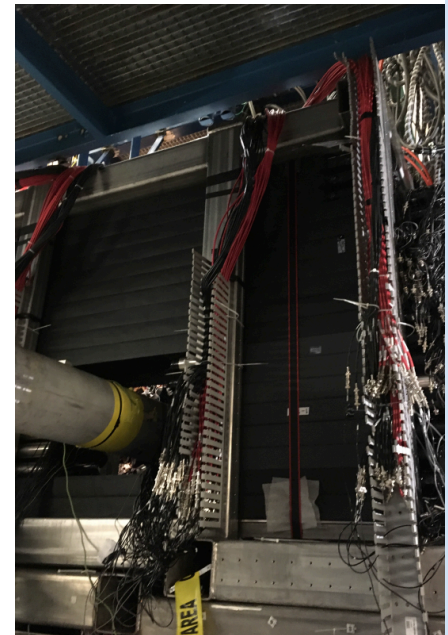
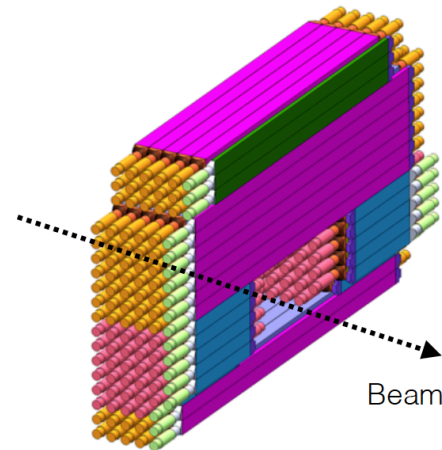
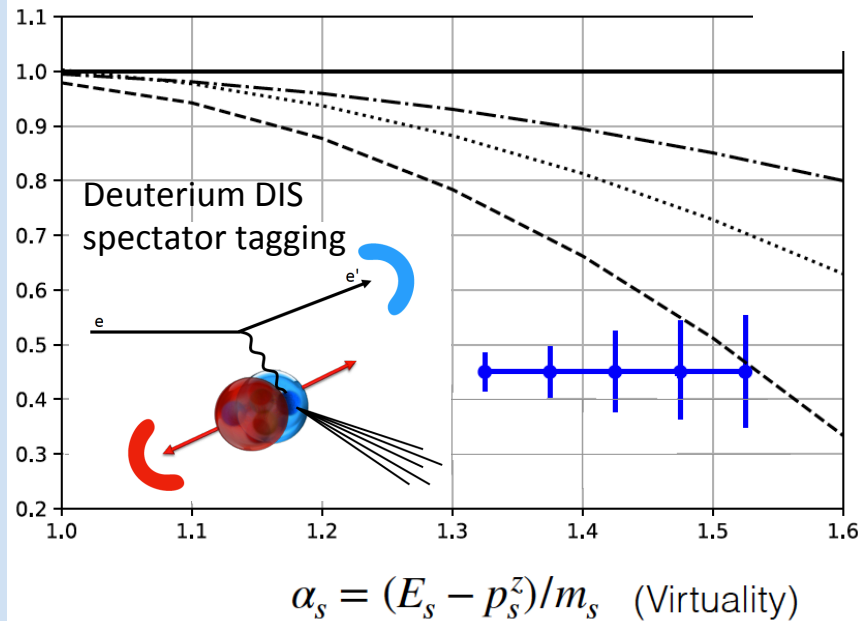
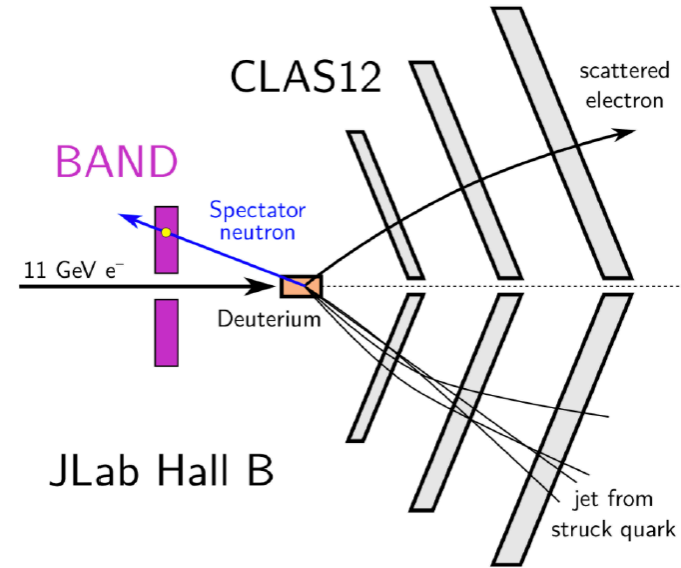
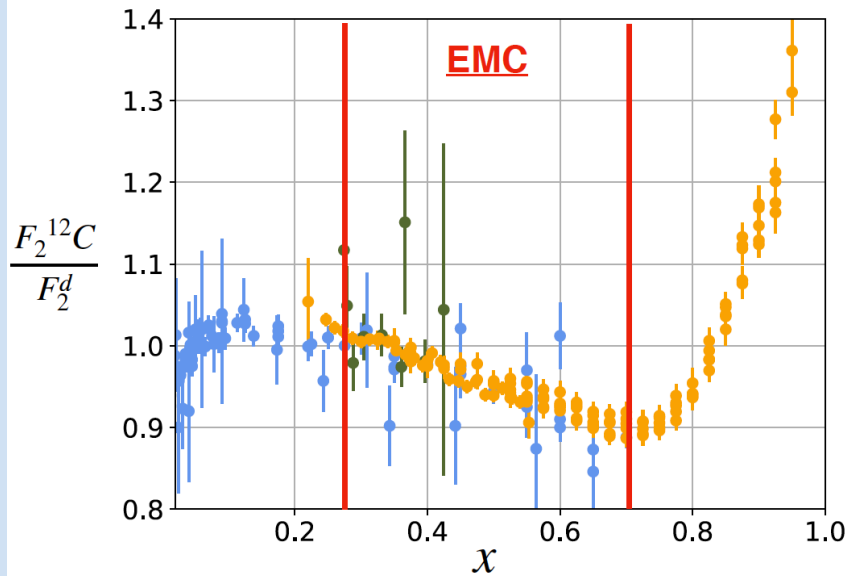
Speaker: Christopher Dilks (Duke University)

Material: [Slides](#) 

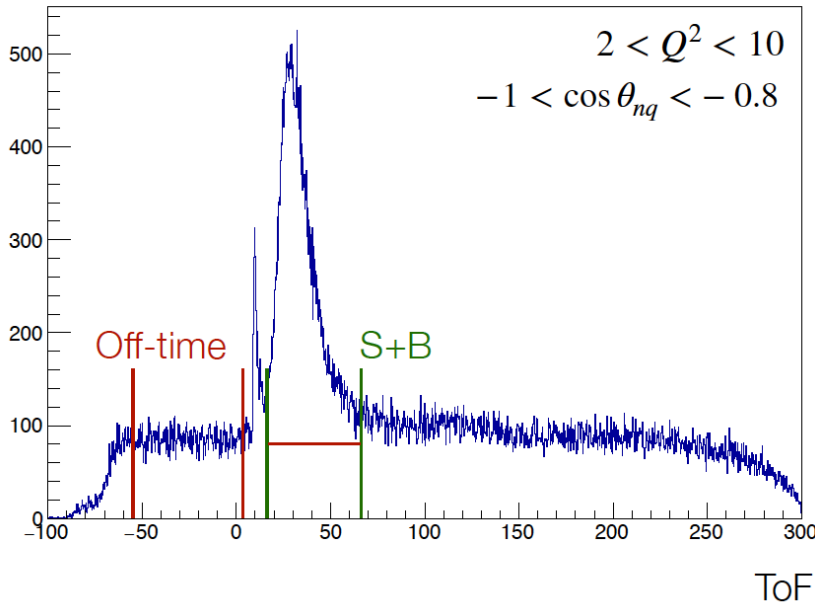
11:55 **Dihadron beam-spin asymmetries for a CLAS12 first publication 15'**

Speaker: Timothy Hayward (William & Mary)

Material: [Slides](#) 

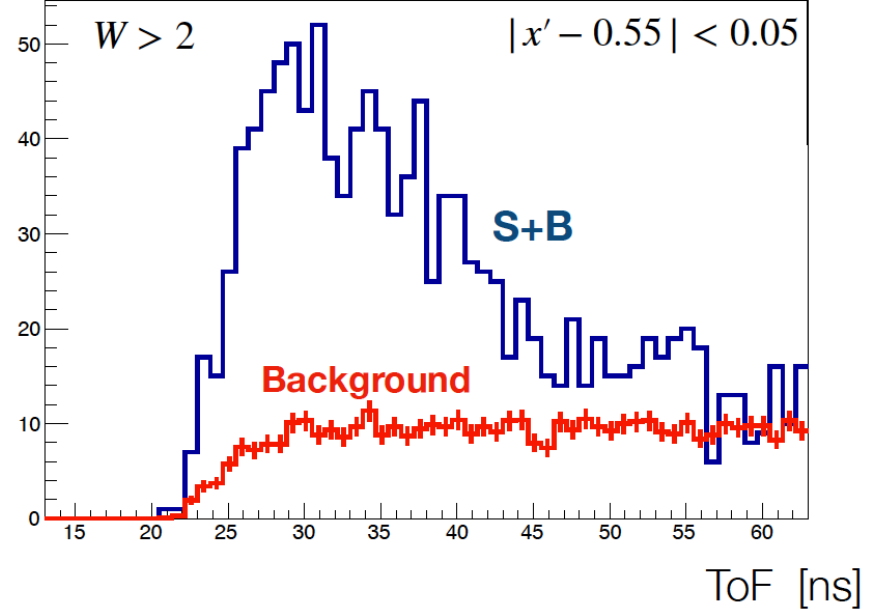


Signal + Background

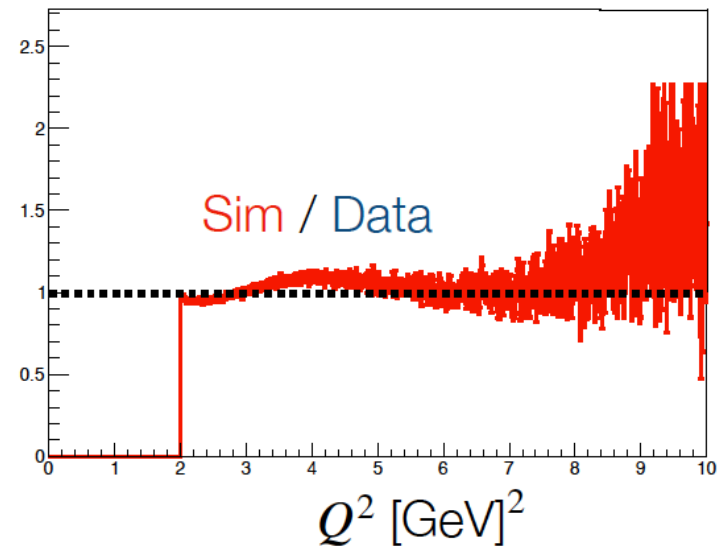
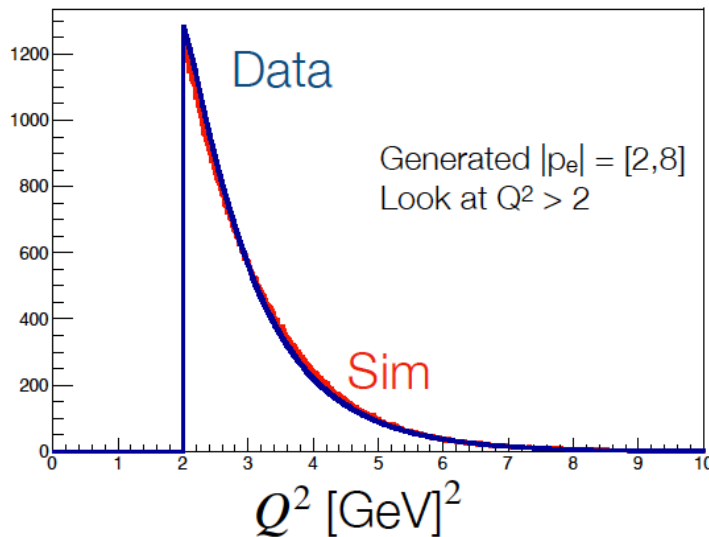


$2 < Q^2 < 10$

$-1 < \cos \theta_{nq} < -0.8$



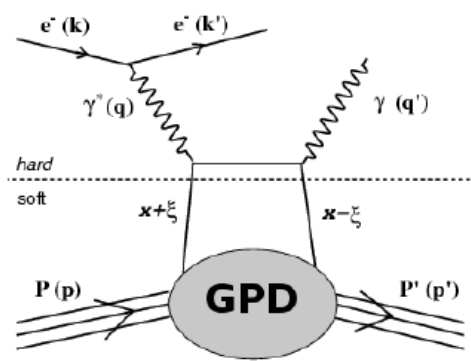
BAND
into
GEMC



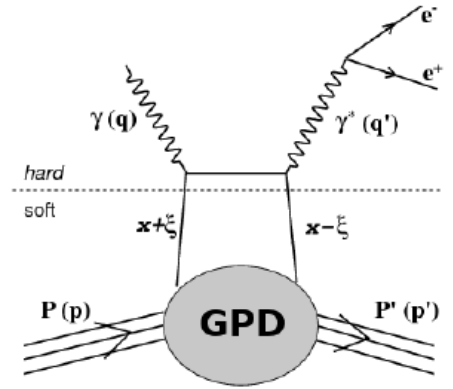
Timelike Compton Scattering with CLAS12 at Jefferson Lab

Pierre Chatagnon, Orsay

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



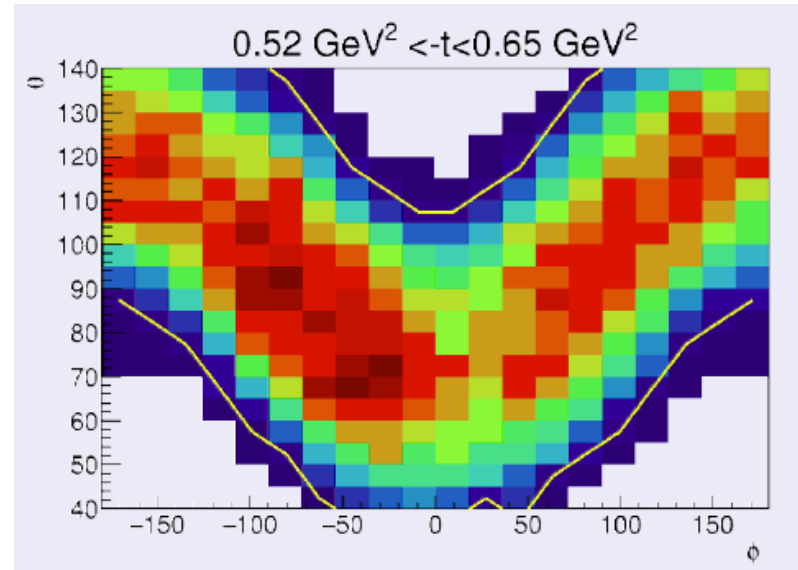
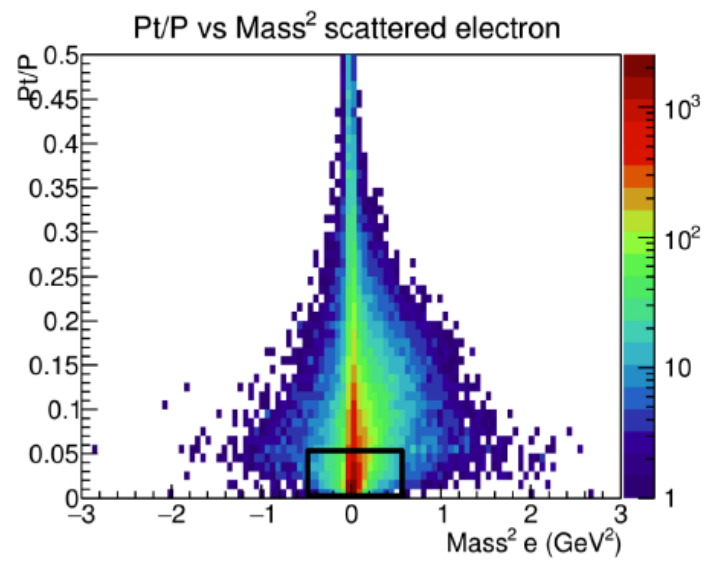
TCS ($\gamma p \rightarrow \gamma^* p$)



$$ep \rightarrow e' \gamma p \rightarrow (e') e^+ e^- p'$$

Exclusive cuts

Acceptance

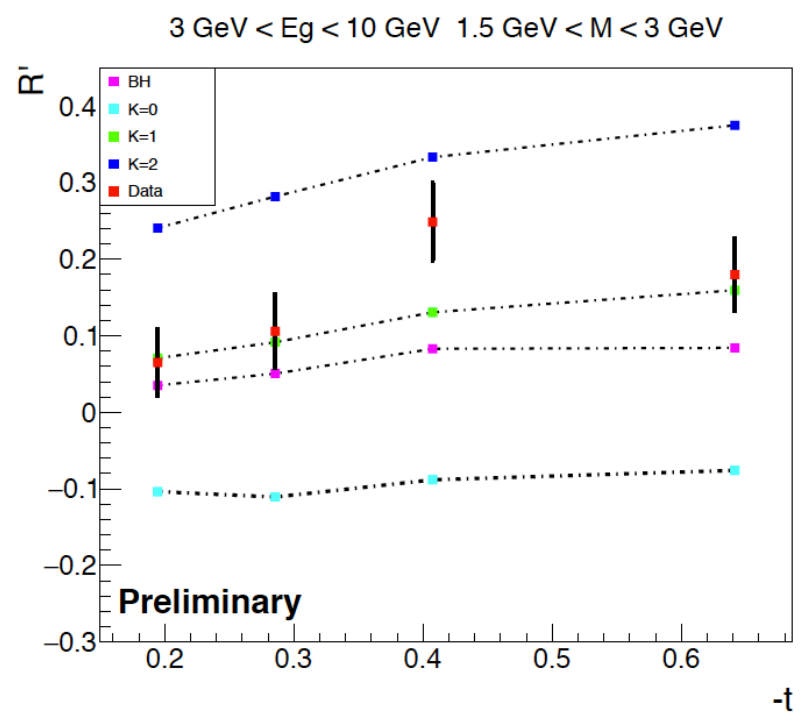
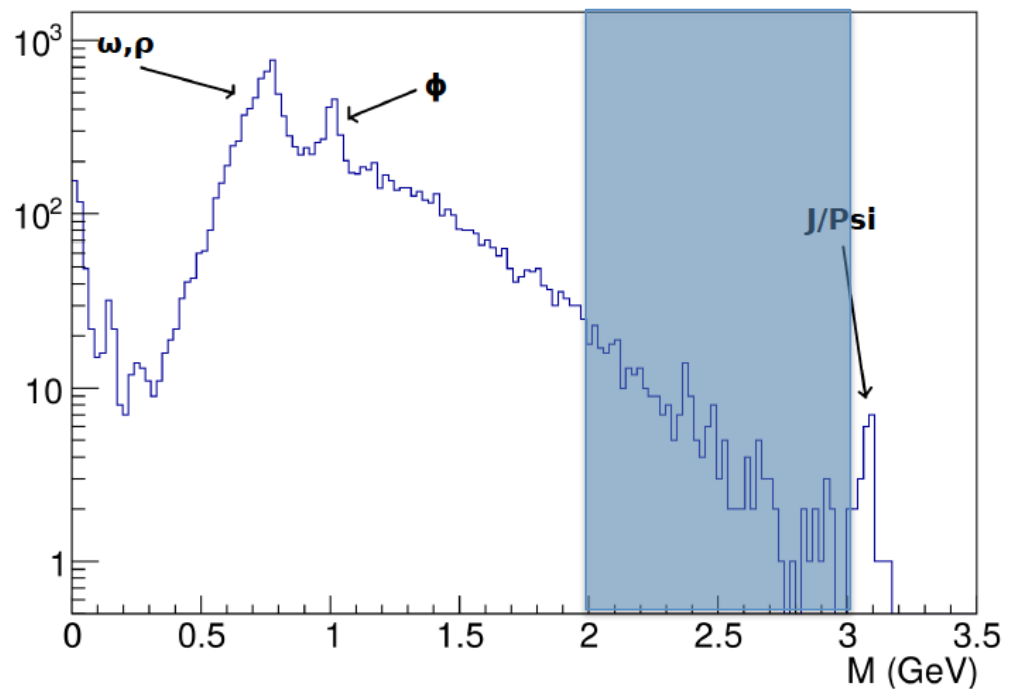


Timelike Compton Scattering with CLAS12 at Jefferson Lab

Pierre Chatagnon, Orsay

$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} = -\frac{\alpha_{em}^3}{4\pi s^2} \frac{1}{-t} \frac{m_p}{Q'} \frac{1}{\tau\sqrt{1-\tau}} \frac{L_0}{L} \left[\cos(\phi) \frac{1 + \cos^2(\theta)}{\sin(\theta)} \text{Re } \tilde{M}^{--} + \dots \right]$$

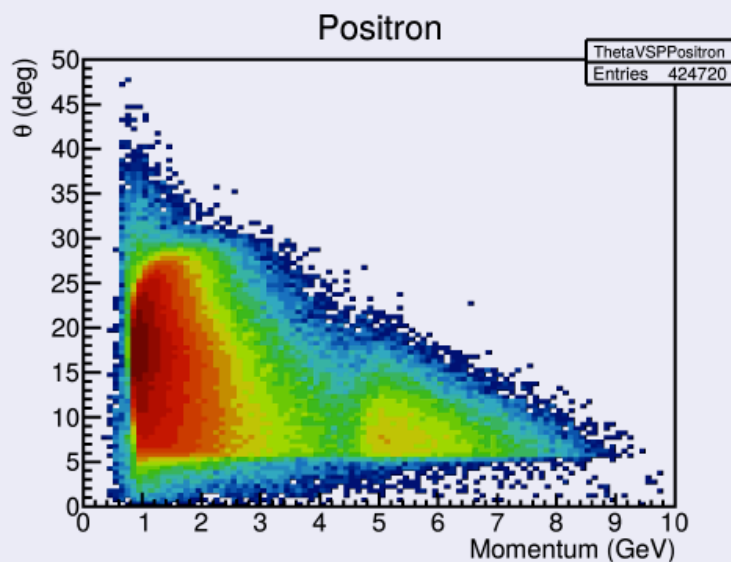
$$\rightarrow \tilde{M}^{--} = \frac{2\sqrt{t_0 - t}}{M} \frac{1 - \xi}{1 + \xi} \left[F_1 \mathcal{H} - \xi(F_1 + F_2) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2 \mathcal{E} \right]$$



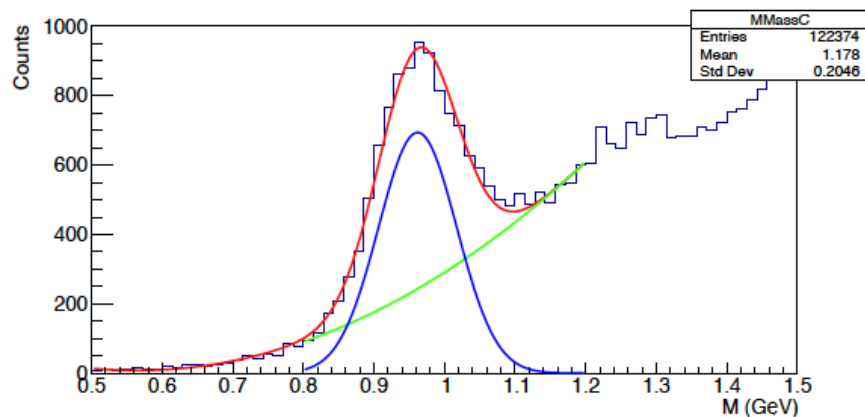
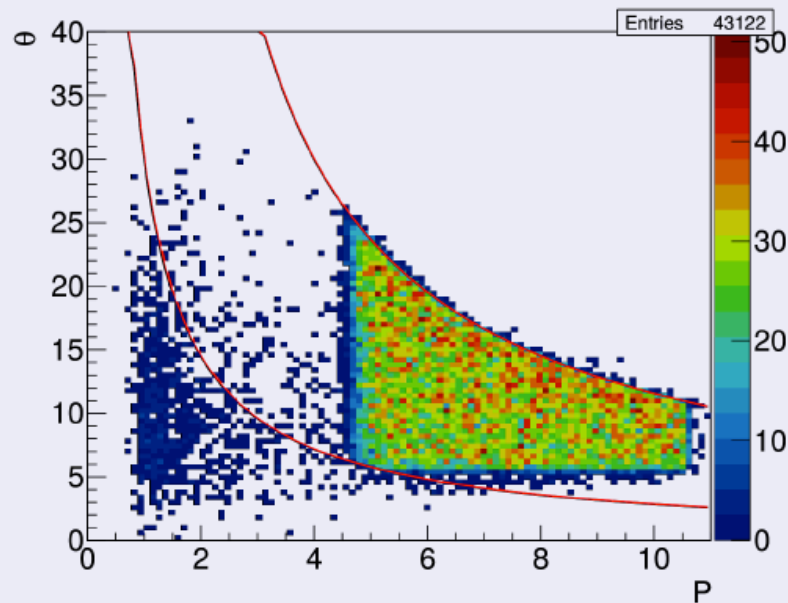
Timelike Compton Scattering with CLAS12 at Jefferson Lab

Pierre Chatagnon, Orsay

Data: clear increase in the number of positron above 4.9 GeV



Simu.: mis-identified pions above 4.9 GeV



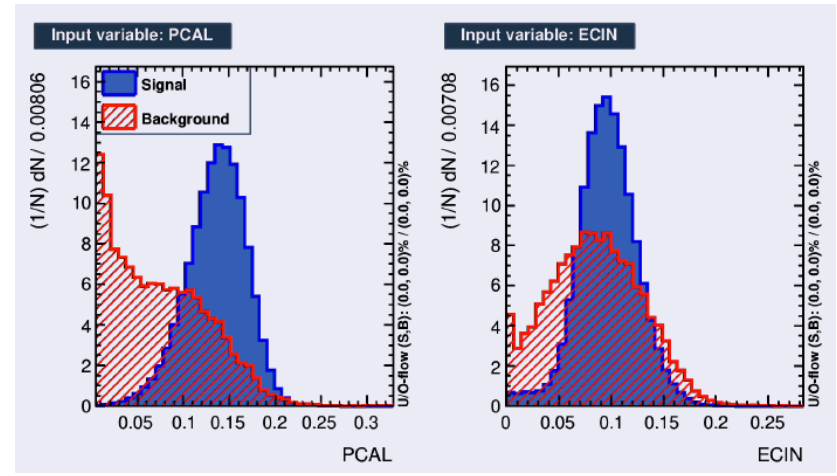
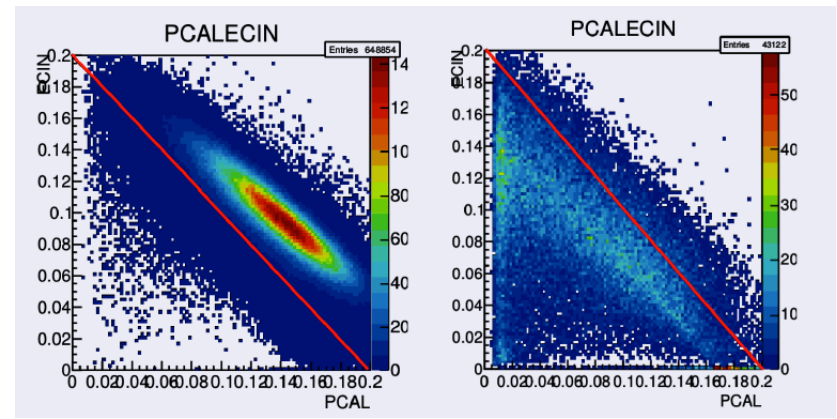
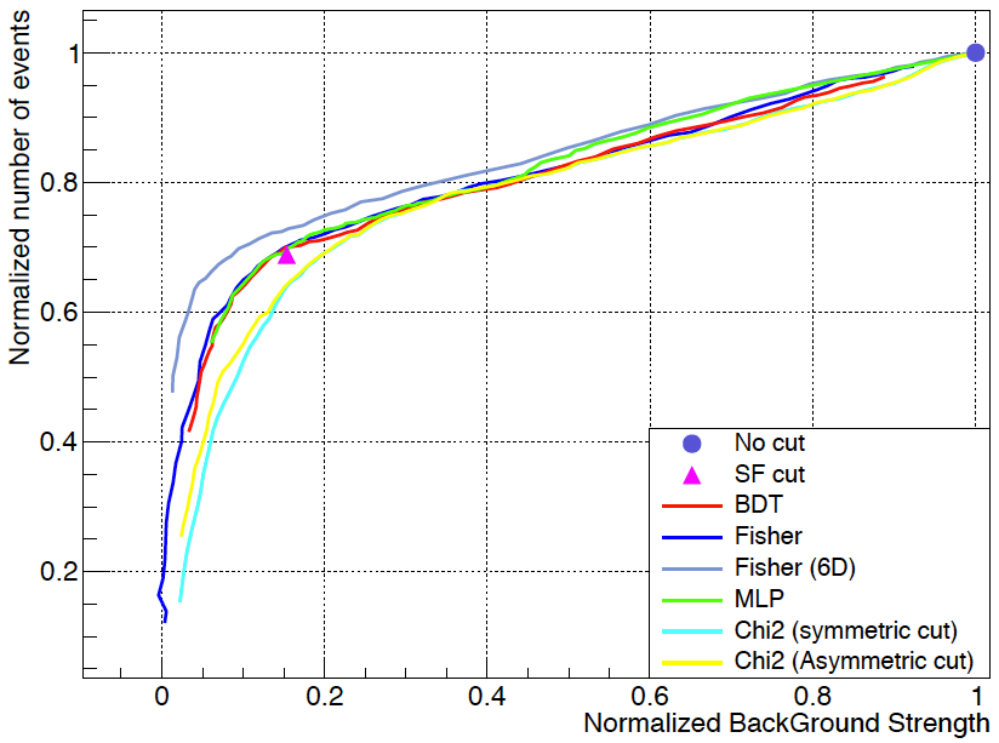
- Skim events with electron in FD and $P < 4.4$ GeV, "positron" (ID -11) in FD and $P > 4.4$ GeV
- Assign m_π to positron, and look for the missing particle $e^- p \rightarrow e^- \pi_{PID -11}^+ X$
- Clear neutron peak

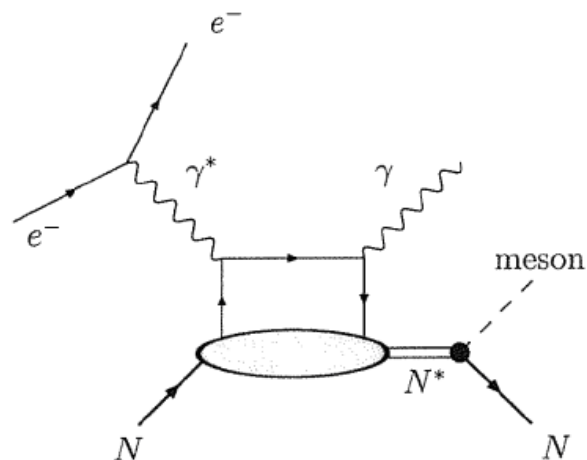
Timelike Compton Scattering with CLAS12 at Jefferson Lab

Pierre Chatagnon, Orsay

Multivariate analysis approach

- Positron/Pion separation above HTCC threshold is a typical **multivariate problem** :
sampling fraction (total, PCAL, ECin, Ecout), shower profile, shower skewness, ...
- Use of the Root/TMVA package <https://root.cern.ch/tmva>



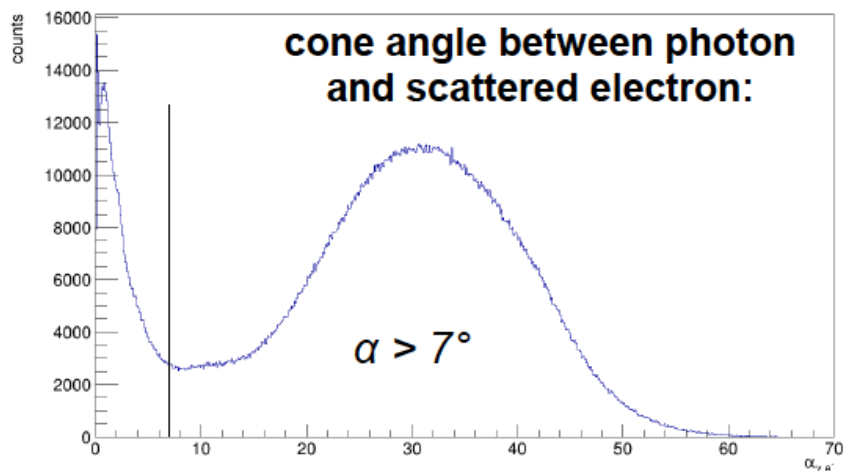


Non diagonal DVCS

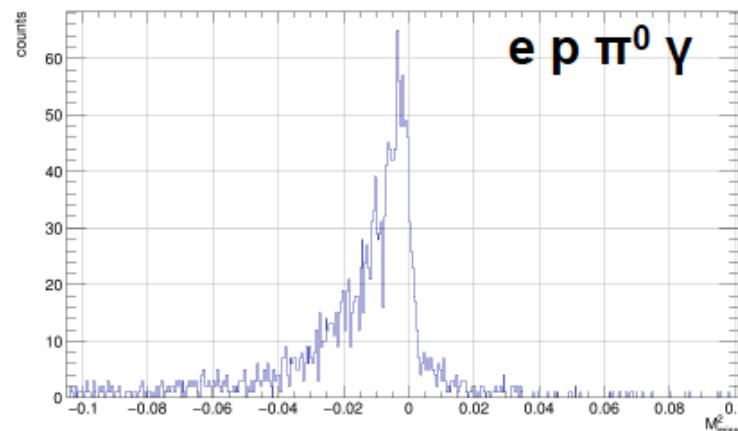
$N \rightarrow \Delta(1232)$ magnetic dipole GPD

unpolarized GPDs: H_M, H_E, H_C, H_4

- Contain explicitly gluonic degrees of freedom
- Non-local which enables the excitation of resonances with arbitrary spin (i.e. 20-plet of the SU(6) spin-flavour group)
- Also exotic configurations will be directly accessible



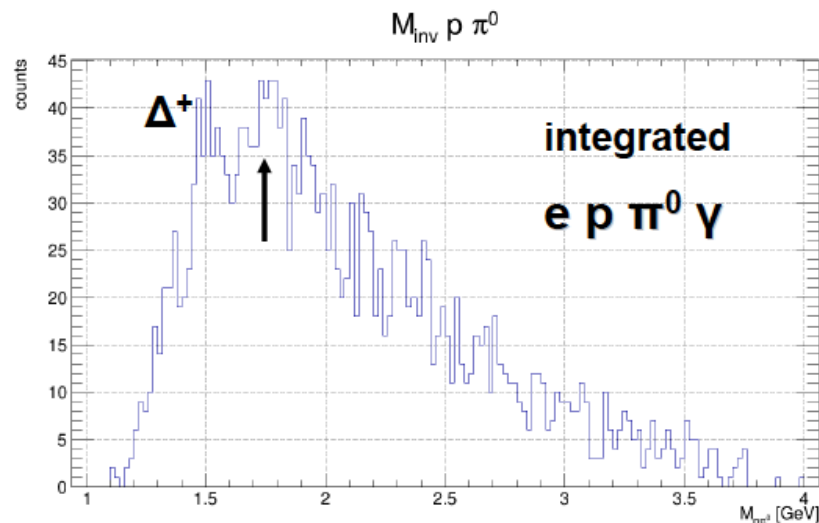
exclusive missing mass



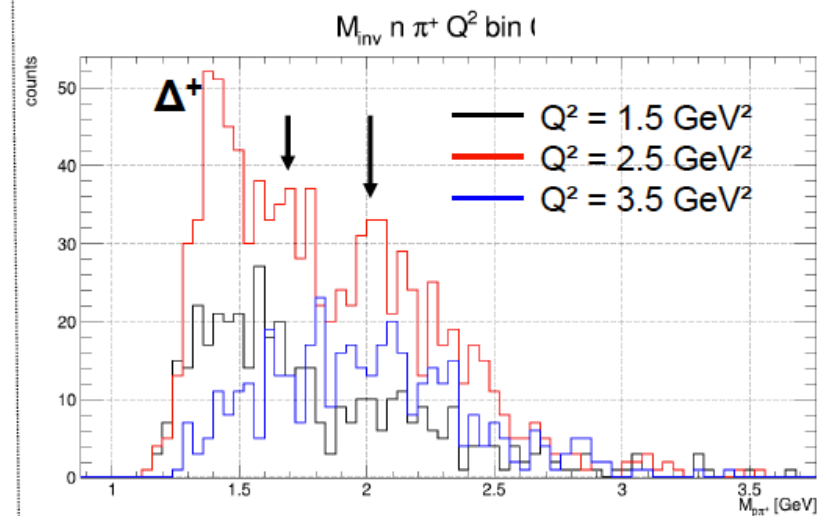
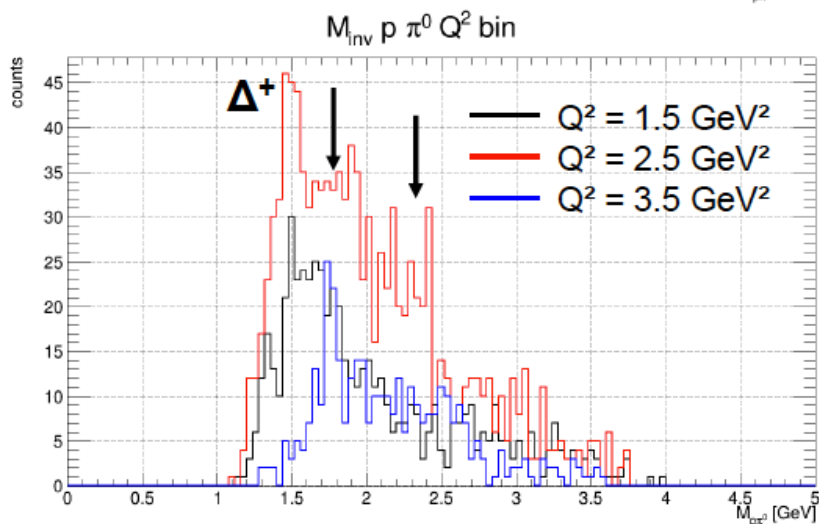
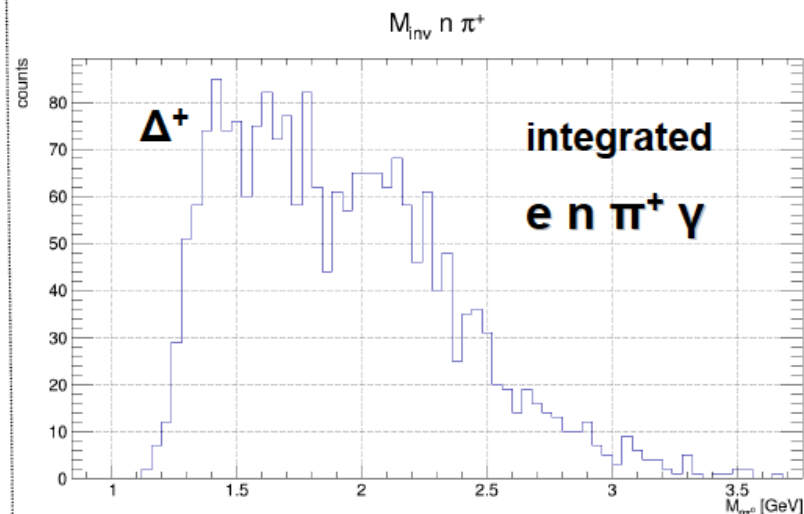
Measurement of transition GPDs and baryon spectroscopy in non-diagonal DVCS

S. Diehl, UCONN

resonance mass for $e p \pi^0 \gamma$

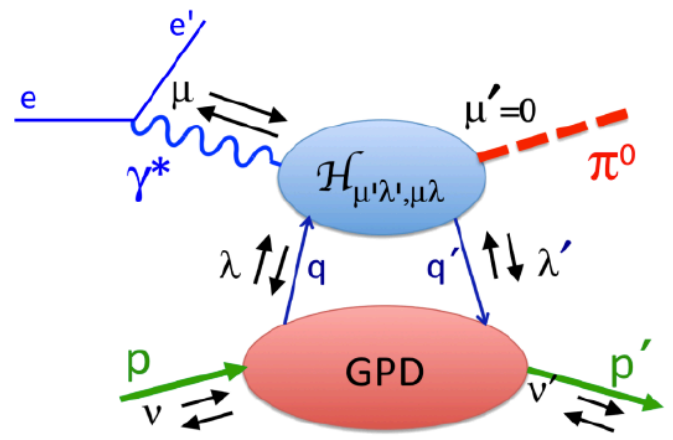


resonance mass for $e n \pi^+ \gamma$



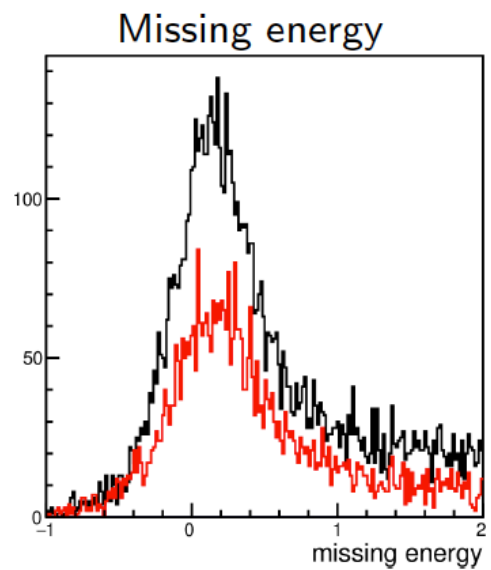
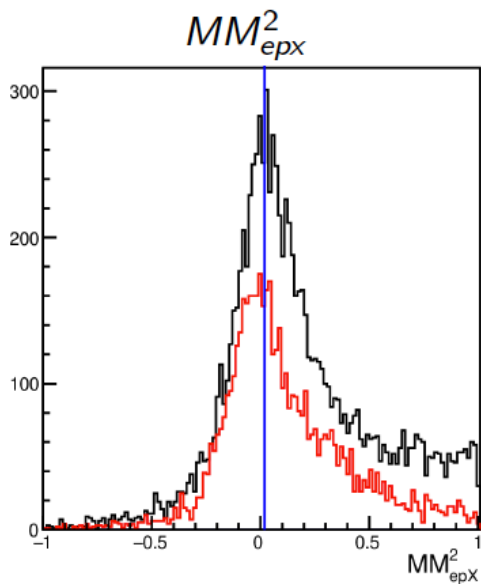
BSA from Deeply virtual π^0 electroproduction measurements with CLAS12

A. Kim, UCONN



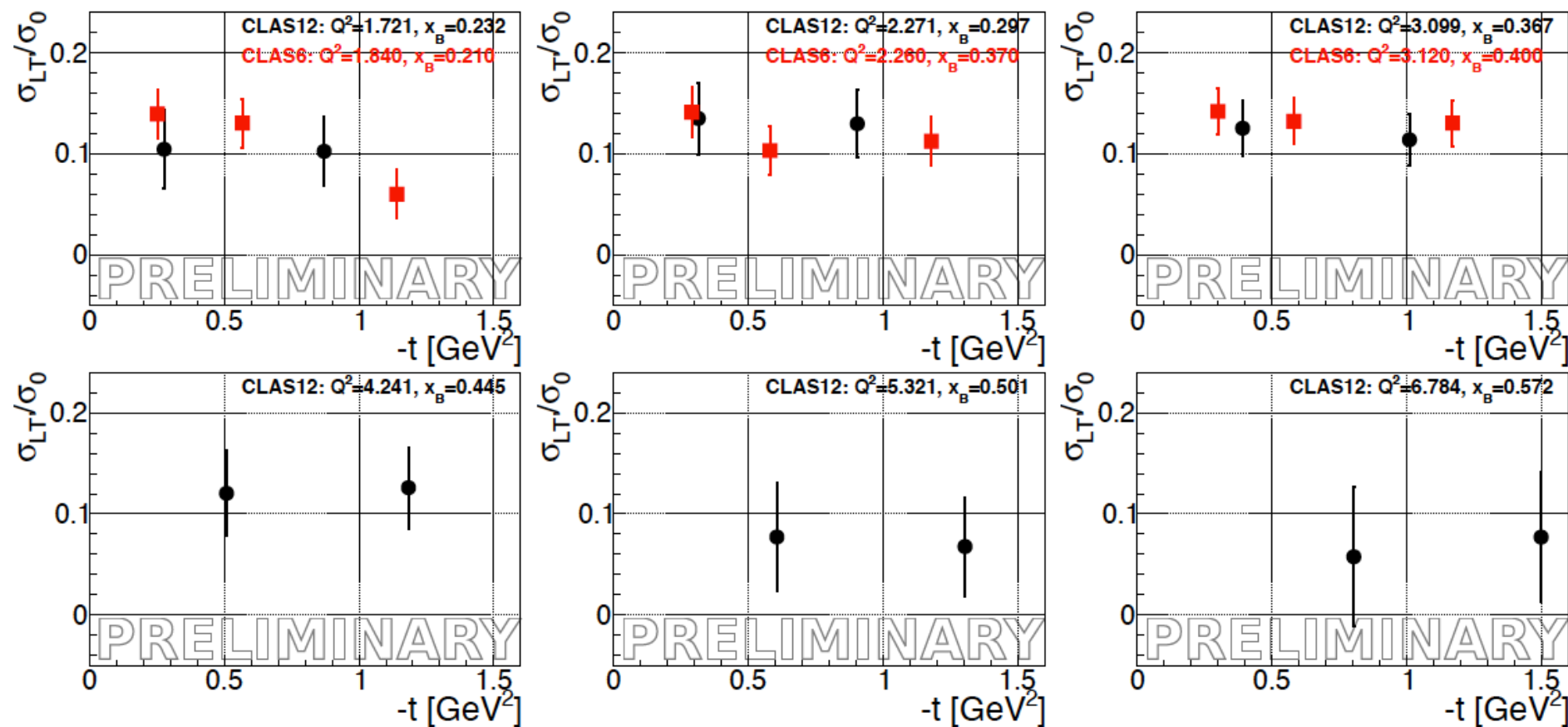
$$\frac{2\pi}{\Gamma} \frac{d^4\sigma}{dQ^2 dx_B dt d\phi_\pi} = \dots + P_b \sqrt{\epsilon(1-\epsilon)} \sigma_{LT'} \sin\phi$$

Exclusive variables [sector 1]: e, p, π^0 detected, $MM_{epx}^2 < 1 \text{ GeV}^2$, $\theta_{X\pi} < 2^\circ$



BSA from Deeply virtual π^0 electroproduction measurements with CLAS12

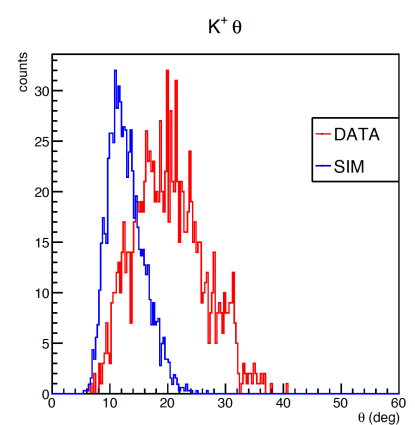
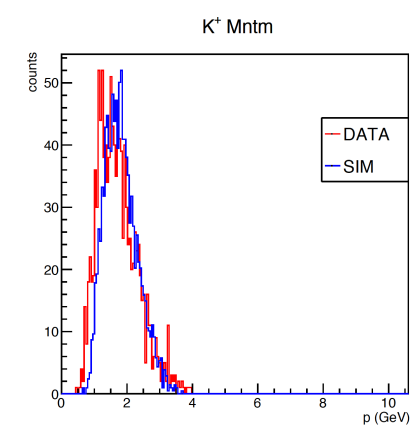
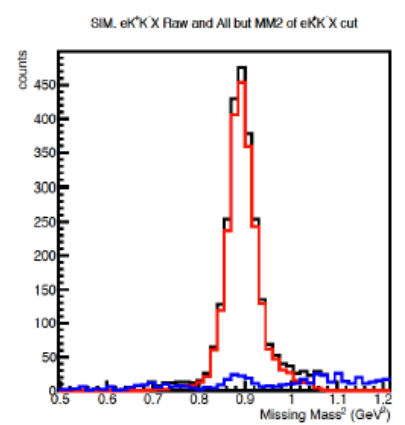
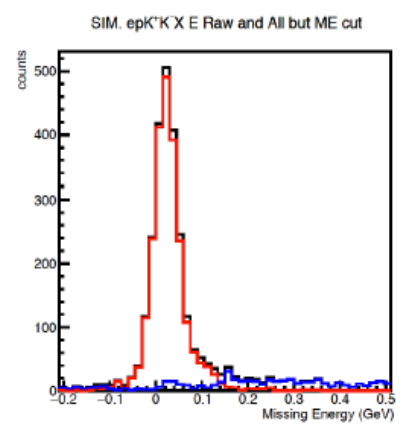
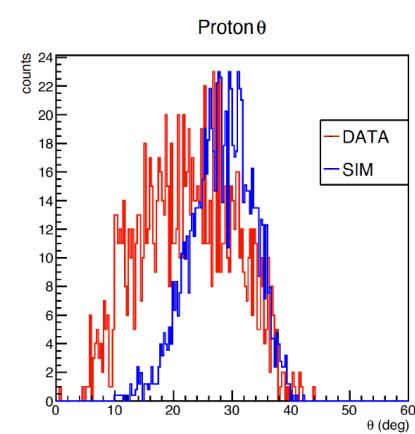
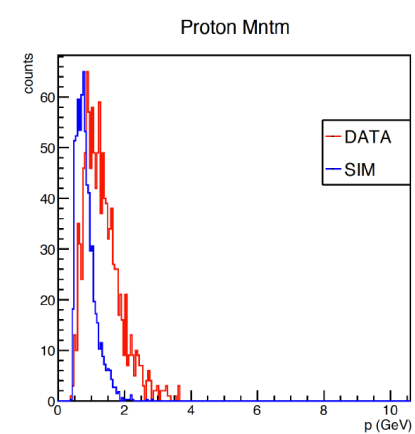
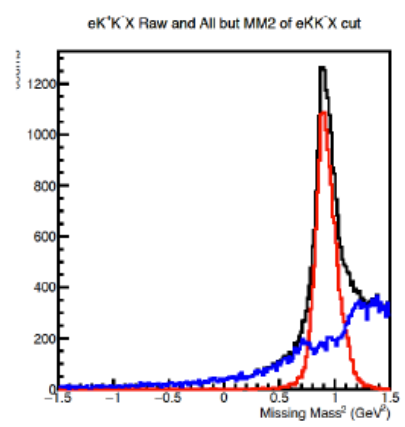
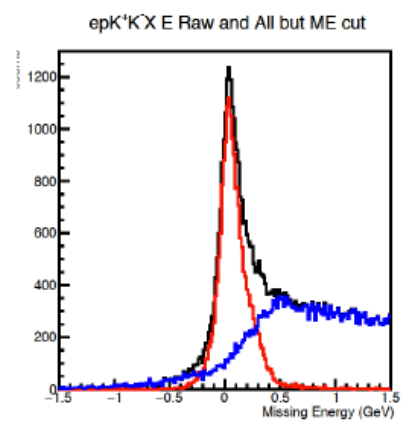
A. Kim, UCONN



Exclusive phi meson electro-production for CLAS12: Comparing Data to Simulation.

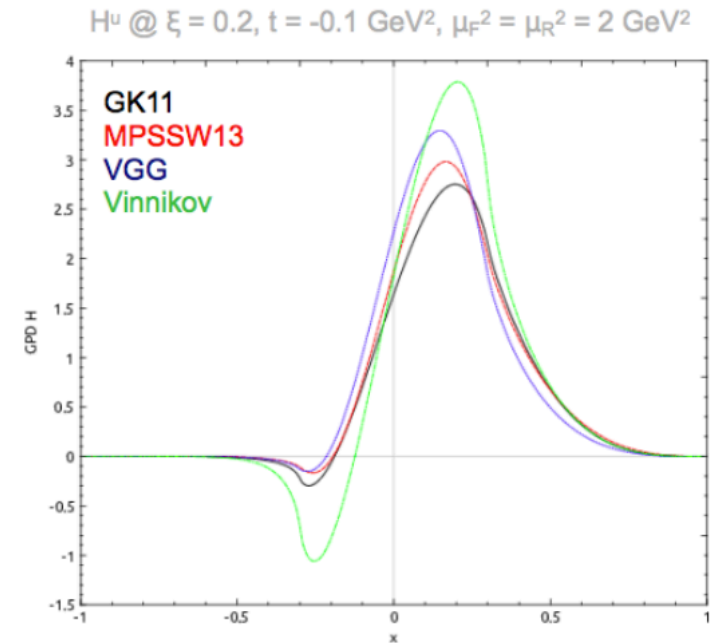
B. Clary, UCONN

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} \sim \dots + \lambda \sqrt{2\epsilon(1-\epsilon)} \left\{ \frac{d\sigma_{LT'}}{dt} \sin(\phi) \right\}$$





- Website: <http://partons.cea.fr>



- Existing modules:
 - GPDs: GK, VGG, Vinnikov, MPSSW, MMS, HM
 - Evolution: Vinnikov's code
 - CFF (for DVCS): LO and NLO evaluation
 - Cross Section (for DVCS): VGG, BMJ, GV

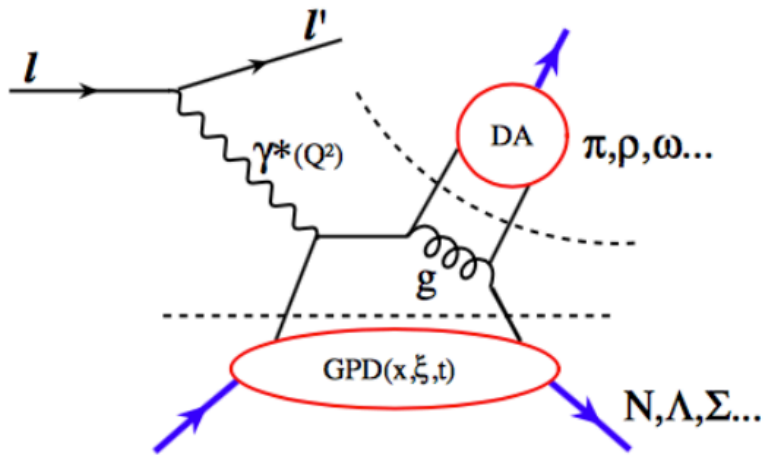
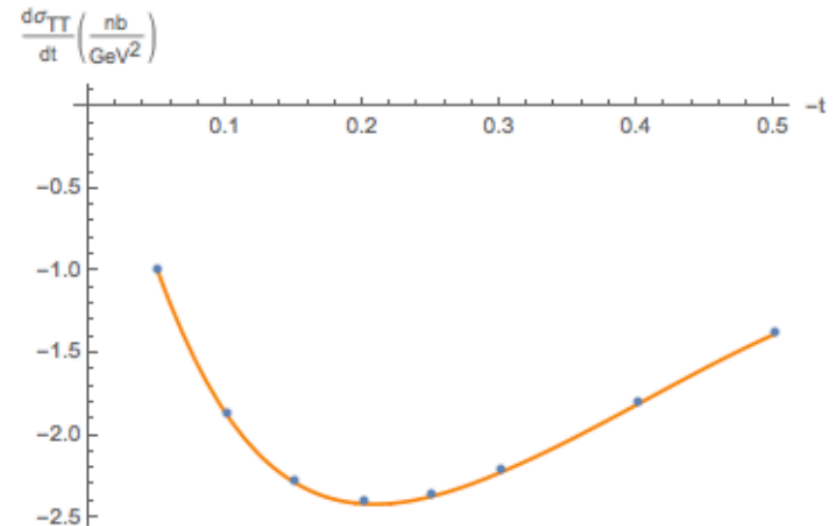
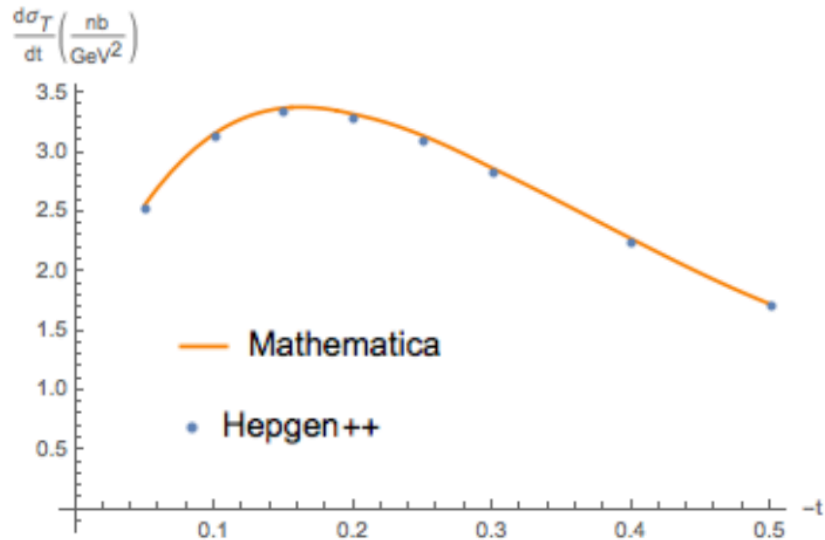
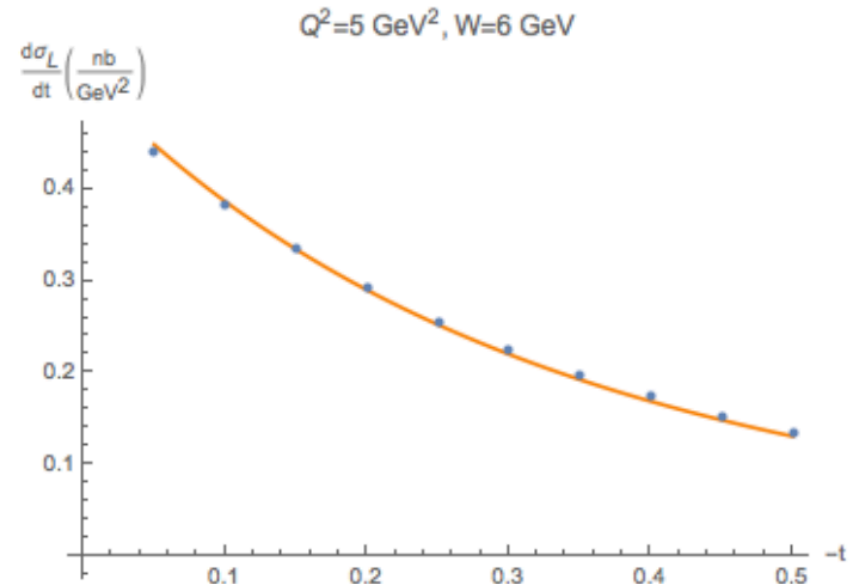


Fig: EPJ Web Conf. 137, 01003 (2017)



Resolution study

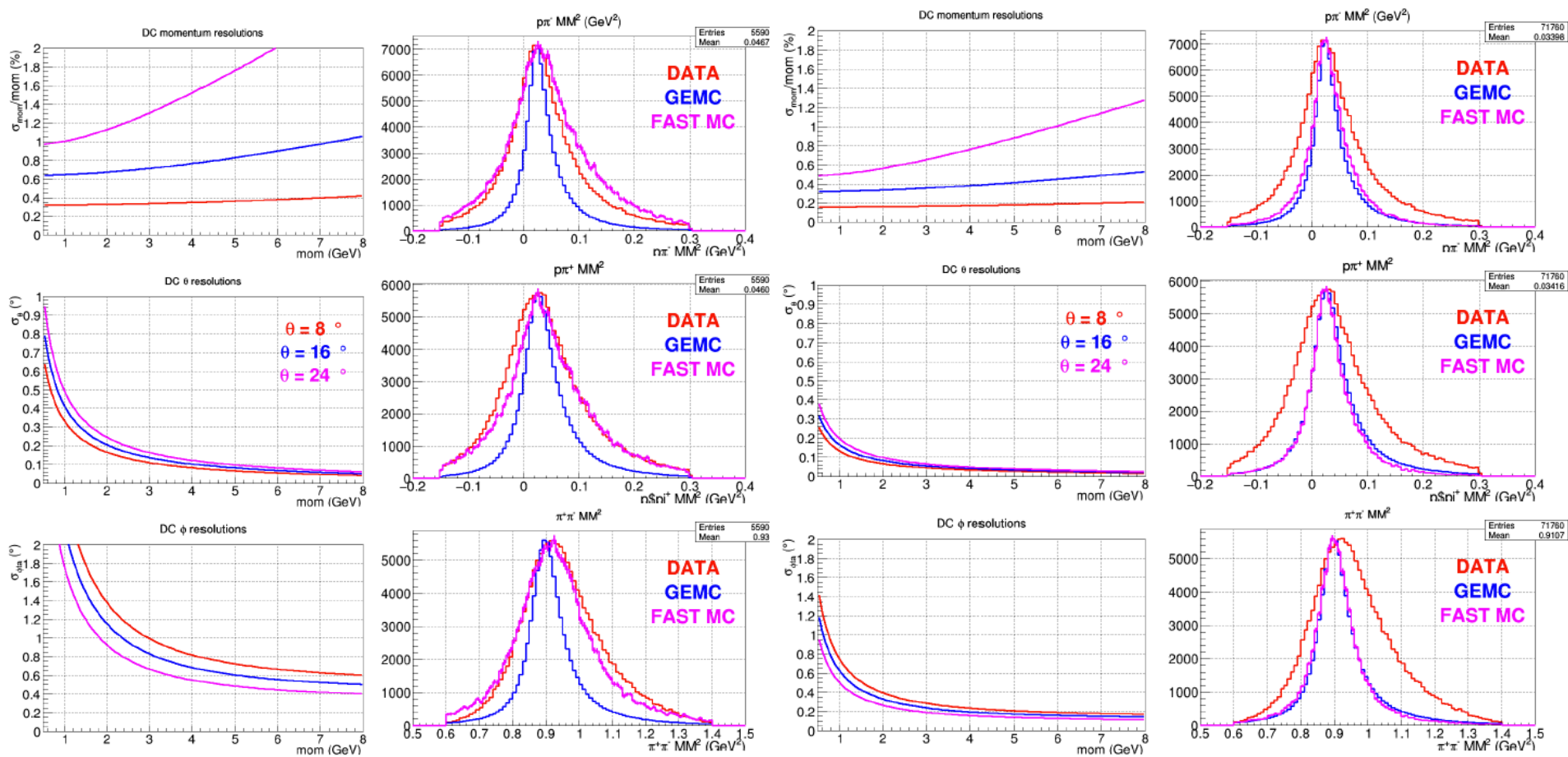
GEMC, Data, Kinematic Fit

F.-X. Girod, UCONN

Resolutions for e , p , π^+ , and π^-

DATA

GEMC



Resolution study

GEMC, Data, Kinematic Fit

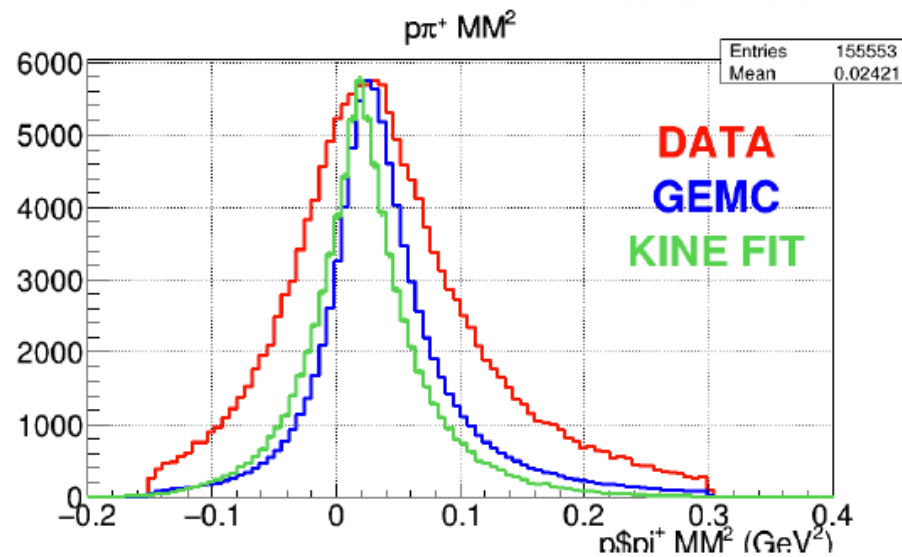
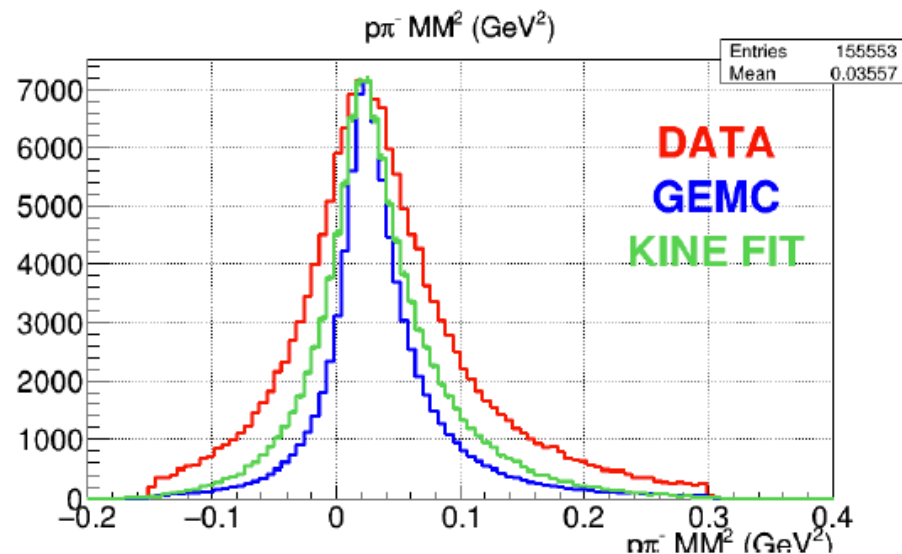
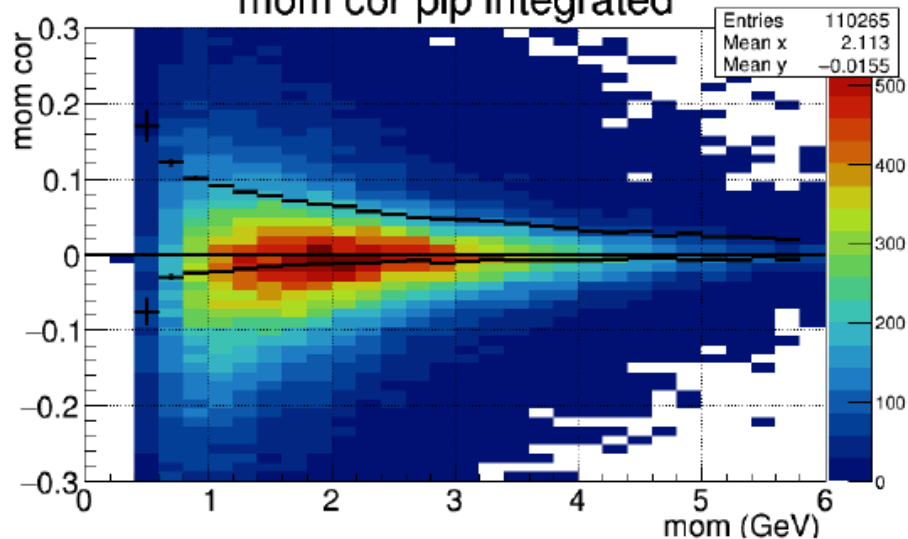
F.-X. Girod, UCONN

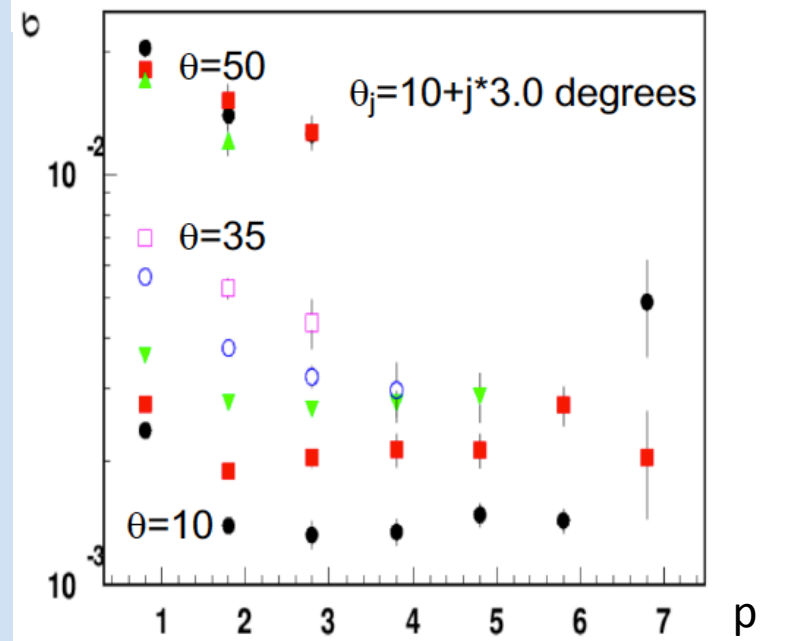
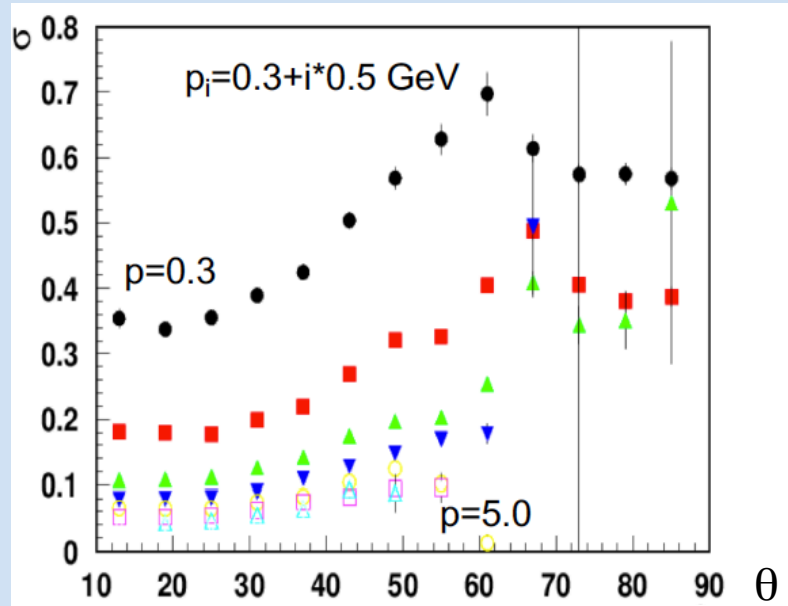
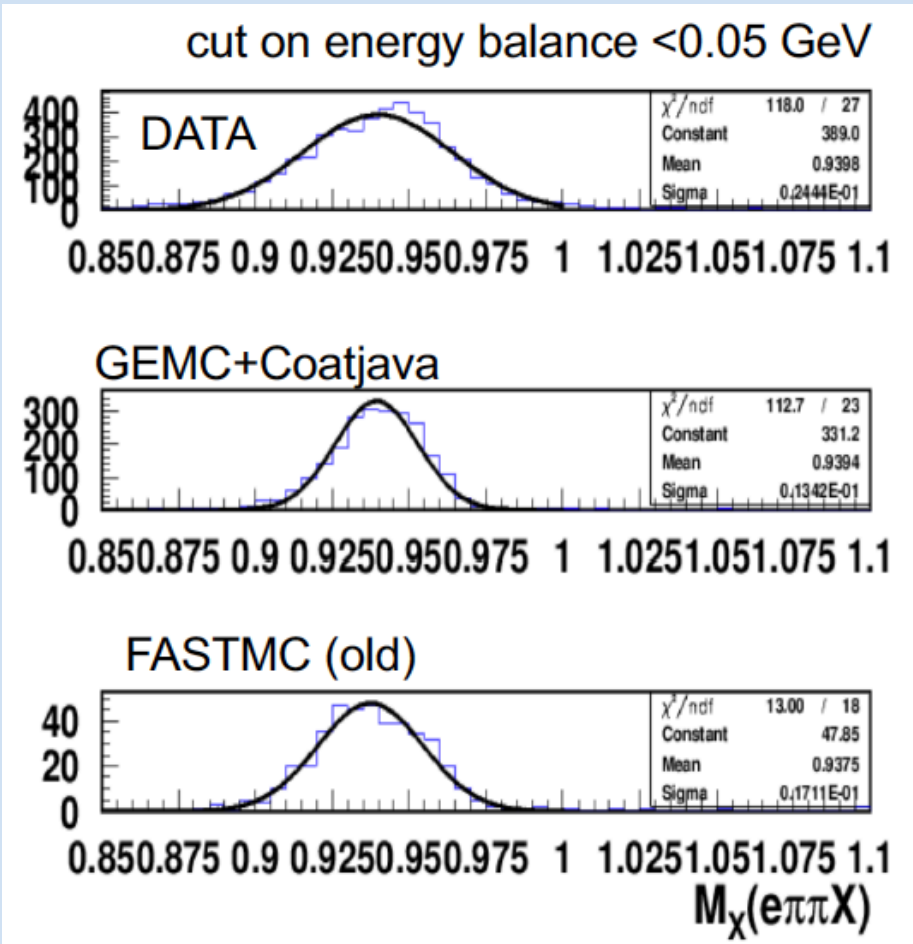
- Input resolutions into Fast MC
- Ad-hoc factors to adjust Fast MC to data
- Perform kinematic fit

Evidence for hadron energy loss:

$$\text{mom cor} = \delta = \frac{p_{\text{rec}} - p_{\text{fit}}}{p_{\text{rec}}}$$

mom cor pip integrated





Pions SIDIS Multiplicity

G. Angelini, GWU

$$\frac{d^2 M^h(x, Q^2, z, P_{hT}^2)}{dz dP_{hT}^2} = \left(\frac{d^4 \sigma^h}{dx dQ^2 dz dP_{hT}^2} \right) / \left(\frac{d^2 \sigma^{\text{DIS}}}{dx dQ^2} \right)$$

$$M_h = \frac{I}{N_{e^-}^{\text{DIS}}} \frac{(N_h^+ + N_h^-)}{\epsilon_h}$$

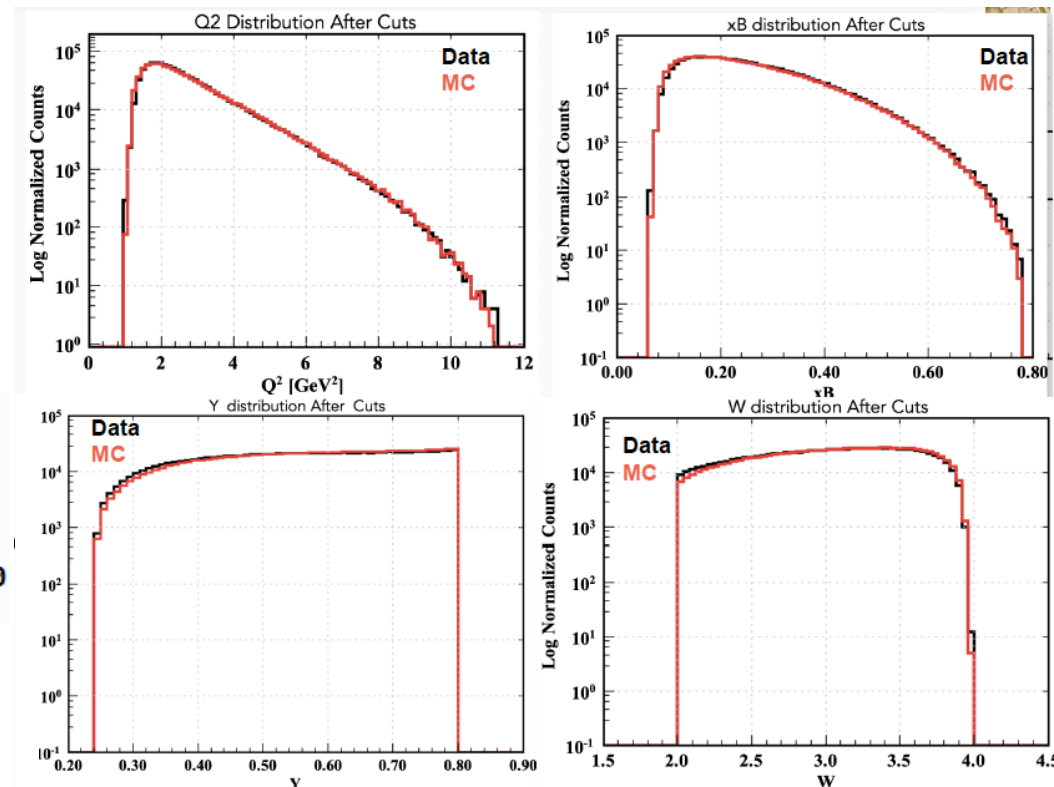
MC based on LEPTO with LUND string model for hadronization is in place thanks effort of Harut Avakian.

100 M inbending events cooked:

`/w/hallb-scifs17exp/clas12/gangel/Simu_DNP19/T-1.00_S-1.0`

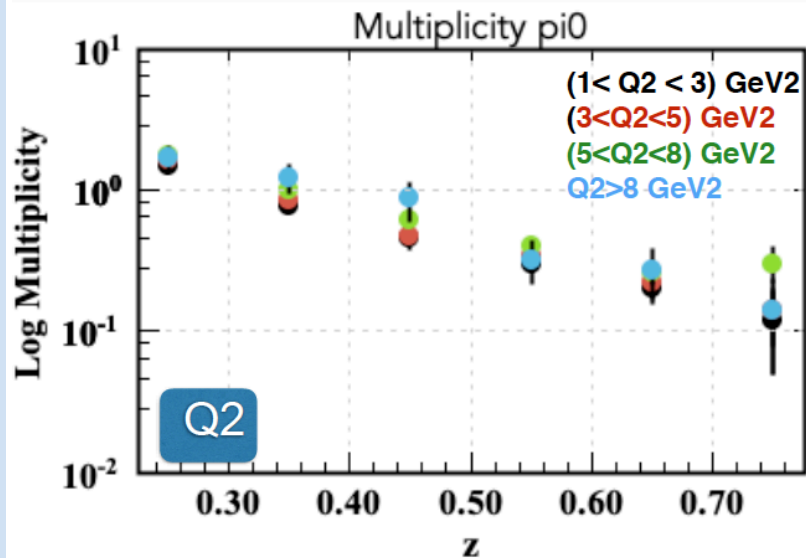
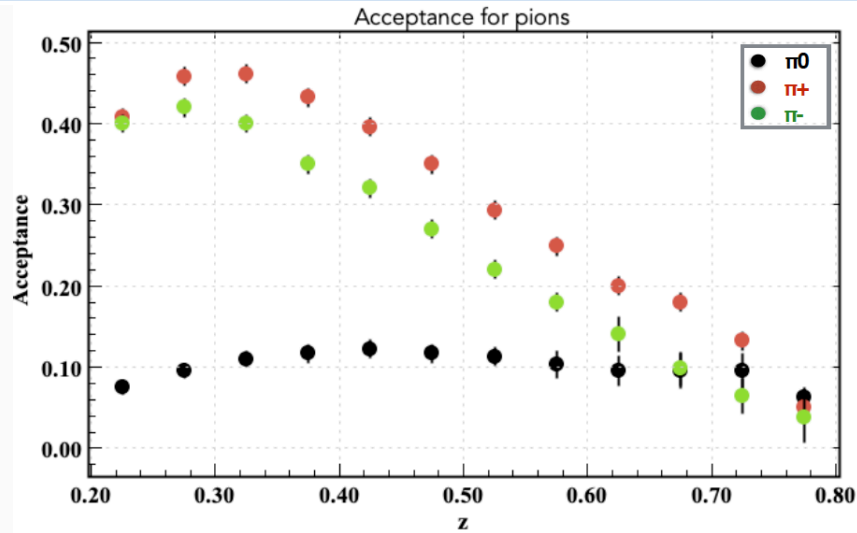
20 M inbending cooked:

`/w/hallb-scifs17exp/clas12/gangel/Simu_DNP19/T+1.00_S-1.0`



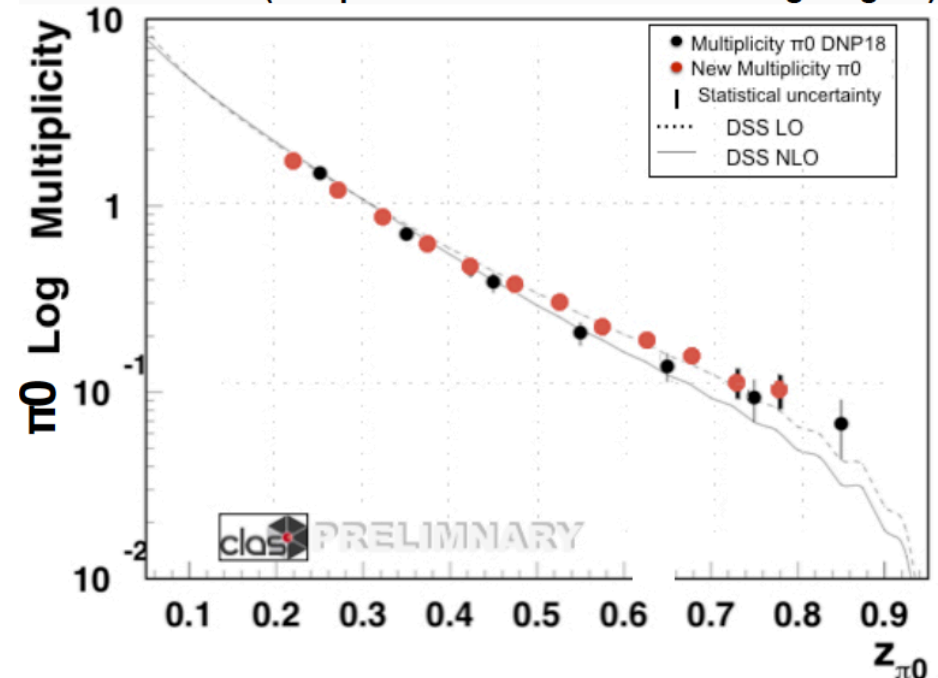
Pions SIDIS Multiplicity

G. Angelini, GWU



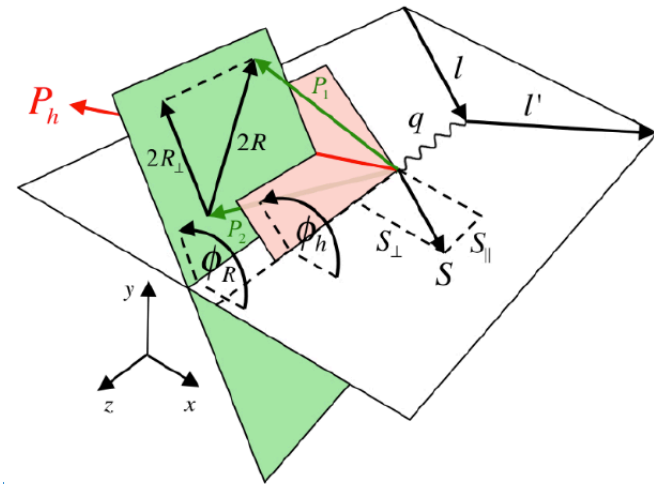
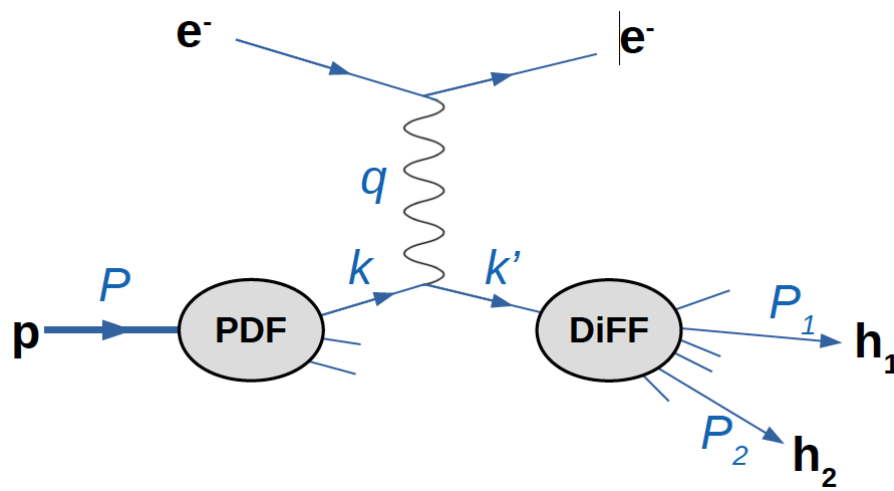
Multiplicity π^0

DNP 18 I used 0.2-0.3% of the approved beam time,
now 1.2-1.3%. (MC production didn't allow me to go higher).



Simultaneous Extraction of Dihadron Beam Spin Asymmetry Modulations

C. Dilks, DUKE



Twist 2:

Twist 3:

$$m = 1 \rightarrow \sin(\phi_h - \phi_R) \quad f_1 G_1^\perp$$

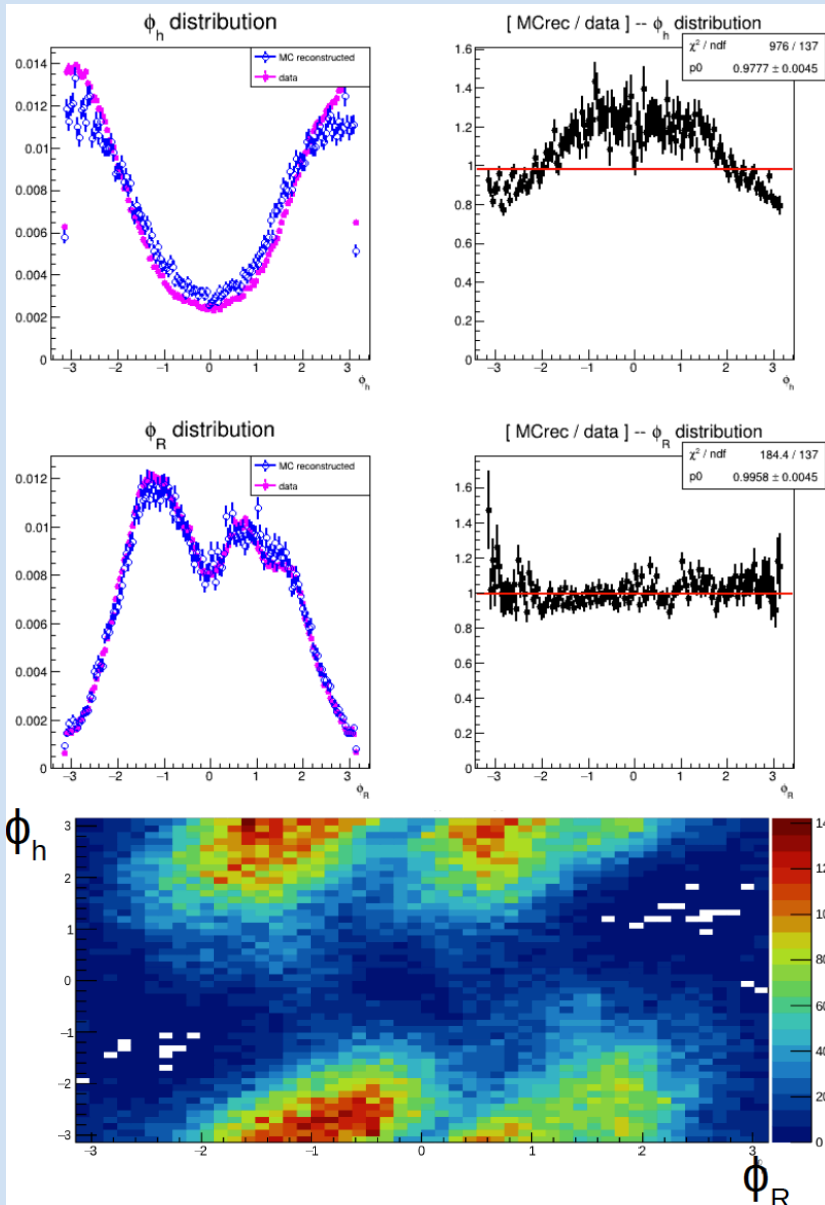
$$m = 1 \rightarrow \sin\phi_R \quad eH_1^\triangleleft$$

$$m = 0 \rightarrow \sin\phi_h \quad eH_1^\perp$$

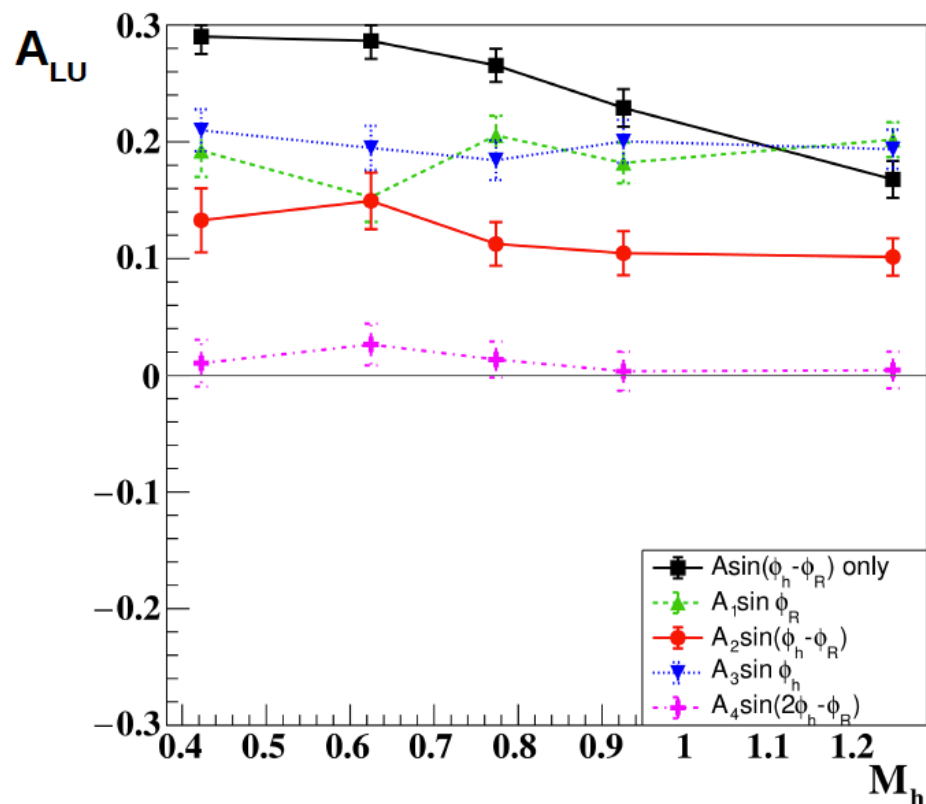
$$m = -1 \rightarrow \sin(2\phi_h - \phi_R) \quad eH_1^\perp$$

Simultaneous Extraction of Dihadron Beam Spin Asymmetry Modulations

C. Dilks, DUKE



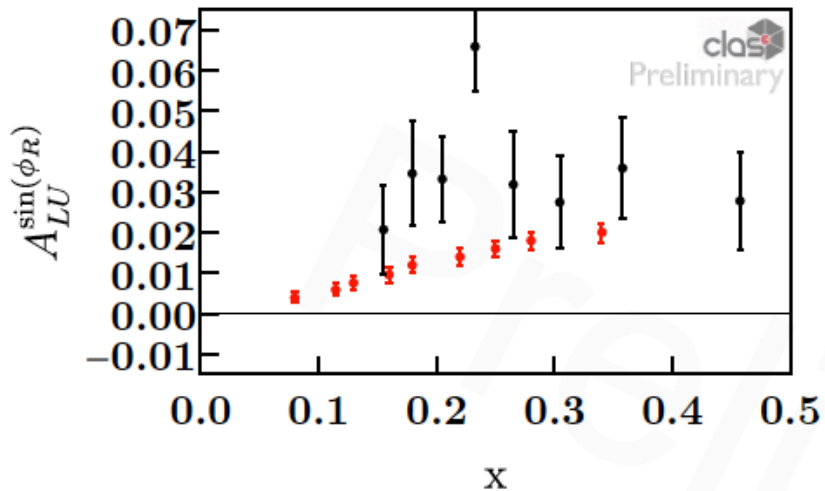
$$A(\phi_h, \phi_R) = 0.20 \sin(\phi_R) + 0.10 \sin(\phi_h - \phi_R) + 0.20 \sin(\phi_h)$$



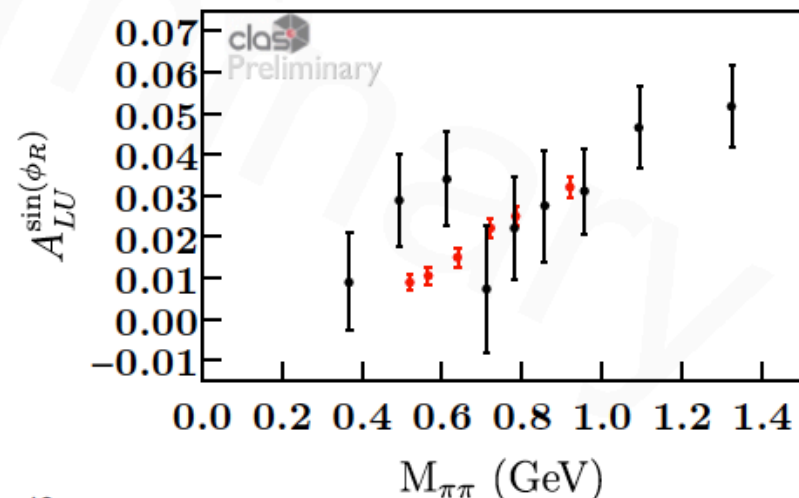
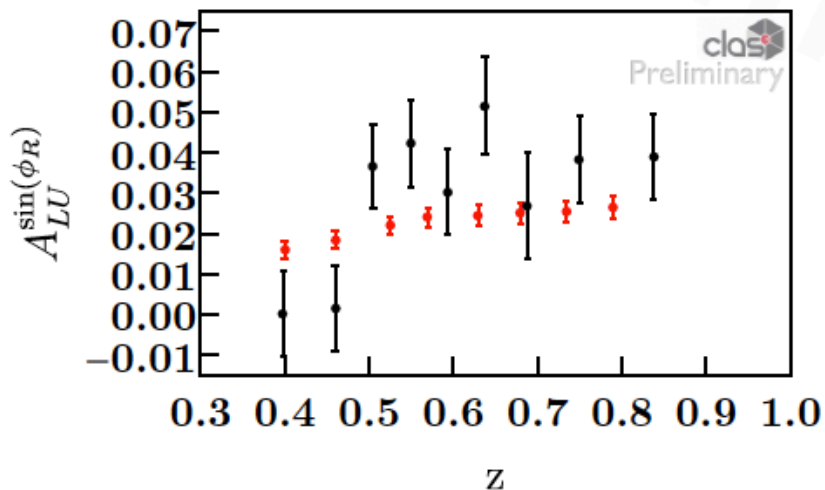
Dihadron beam-spin asymmetries for a CLAS12 first publication

T. Hayward, W&M

Working plan to be among the first CLAS12 publications



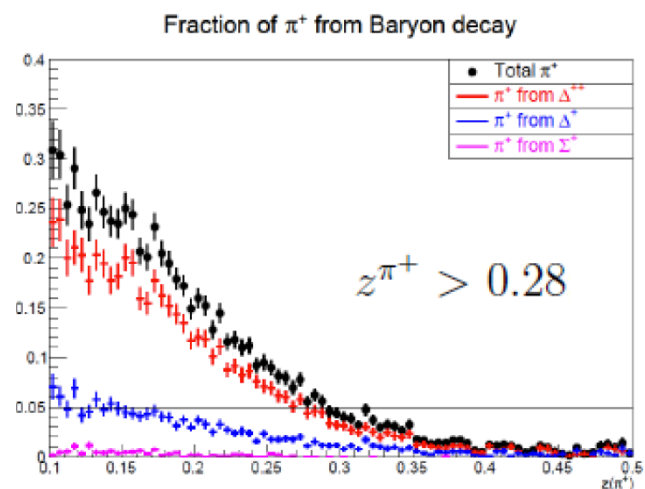
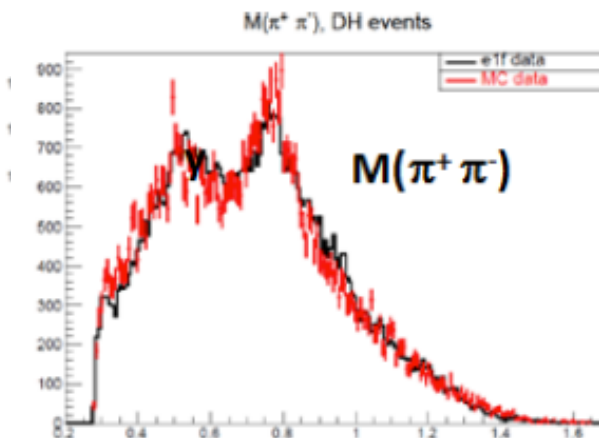
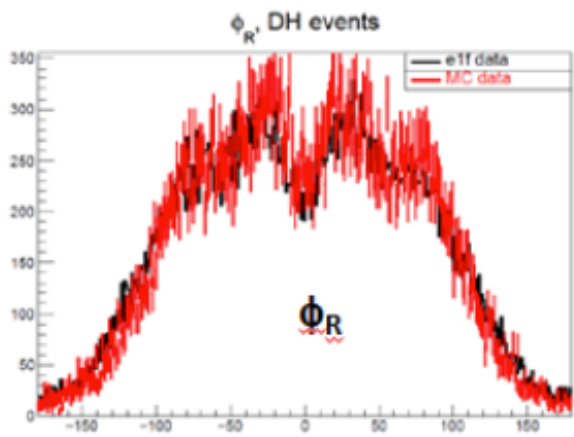
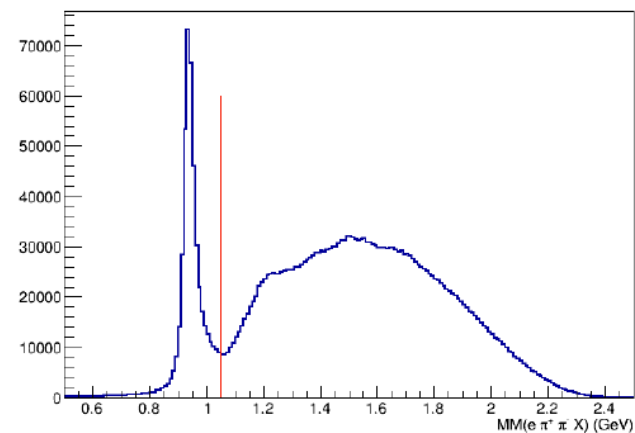
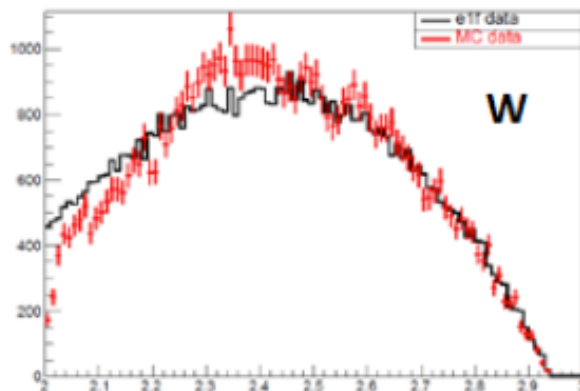
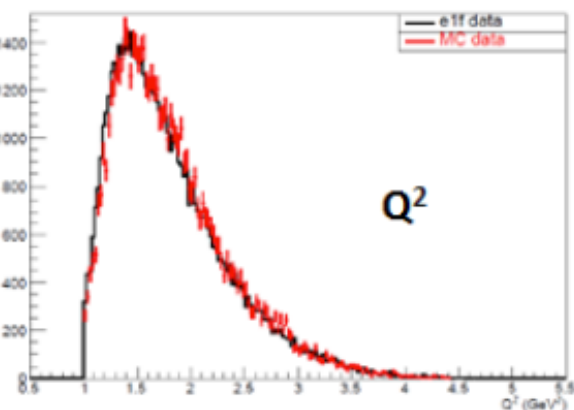
- CLAS12 (Data)
- Spectator (Model)



Di-hadron beam spin asymmetry with CLAS data

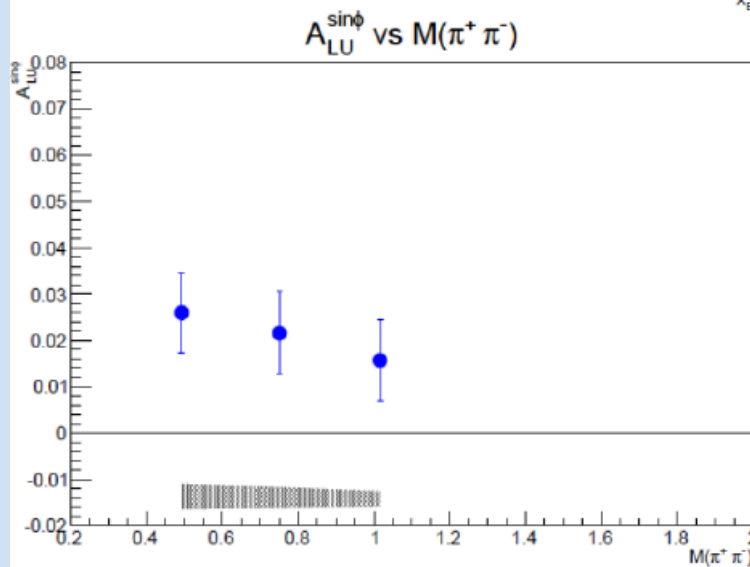
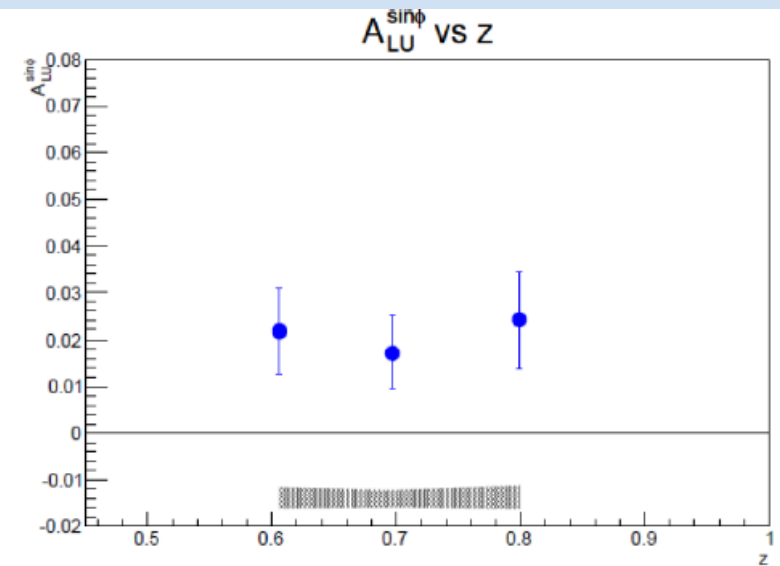
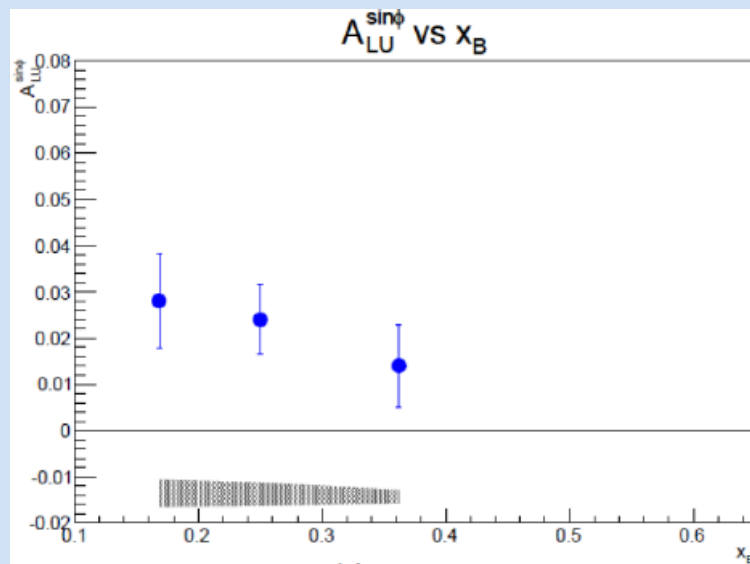
M. Mirazita, INFN-LNF

Revisiting a study under analysis review till 2016



Di-hadron beam spin asymmetry with CLAS data

M. Mirazita, INFN-LNF



- **Asymmetry amplitudes of the order of 2%**
- **Small kinematic dependence**