Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, 9th March 2018

Publications:

CLAS 2017-13
Measurement of the Q^2 dependence of the deuteron spin structure function g_1 and its moments at $0.02<Q^2<0.7$ GeV^2 with CLAS,
K. Adihari, published on Phys. Rev. Lett.

CLAS 2016-10
Determination of the proton spin structure functions for $0.05 < Q^2 < 5.0$ GeV^2 using CLAS
R. Fersch, accepted by Phys Rev C

CLAS 2017-06
Semi-inclusive π^0 target and beam-target asymmetries from 6 GeV electron scattering with CLAS
S. Jawalker, submitted to Phys. Lett. B

CLAS 2017-12
Hard exclusive pion electro-production at backward angles with CLAS,
K. Park, submitted to Phys. Rev. Lett.

CLAS 2017-09
Measurement of Unpolarized Cross Sections and Polarized Cross Section Differences for Deeply Virtual Compton Scattering (DVCS) on the proton at the Jefferson Laboratory with CLAS, at $0.1 <x_B < 0.58$, $1.0 <Q2<4.8$ GeV^2, and $0.09<-t<2.0$ GeV^2,
H. Saylor, under revision for Phys. Rev. C

Ad Hoc Review

Analysis	Data	Lead Author	In progress
Beam spin asymmetries of ep->epη in the deep inelastic regime	**e1f**	**A. Kim**	Done Sep 17

Analysis Review

Analysis	Data	Author	In progress
Exploring the structure of the proton via semi-inclusive pion electroproduction	**e1f**	**N. Harrison** **K. Joo**	Done Feb 18
Beam asymmetries in exclusive π^+ electro production for W> 1.7 GeV from e16	**e16**	**P. Bosted**	Ongoing

Analysis Review

Analysis	Data	Author	In progress
Exclusive electroproduction of the f0(980) and f2(1270) on the proton with CLAS	**e1f**	**B. Garillon** **S. Niccolai**	Brice busy with other project
Di-hadron beam spin asymmetry in SIDIS electro production	**eg1-dvcs**	**S. Pisano**	Silvia busy with other project
Deep-virtual production of the ρ^+ meson off the proton	**e1-dvcs**	**A. Fradi**	Ahmed busy with other projects. Slow progress
Semi-inclusive pion production	**e16**	**M. Osipenko**	Working on a better alignment
Time-like Compton scattering	**g12**	**I. Abayrak**	Last record 2015

DPWG Meeting, 8-9th March 2018

Thursday 8th:

Hard exclusive and future projects (morning)

SIDIS (afternoon)

Friday 9th:
DVMP mini-workshop (Friday afternoon)

Deep Processes Working Group

Remote connection: https://bluejeans.com/675947672

Convener: Mr. Marco Contalbrigo (INFN Ferrara)

13:30	**Theoretical Overview of Status of DVMP** *40'*	Speaker: Christian Weiss (Jefferson Lab)
14:10	**Overview and status of phi experiment** *25'*	Speaker: Francois-Xavier Girod (JLab)
14:35	**Analysis of pi0 at 12 GeV** *25'*	Speaker: Andrey Kim (UCONN)
15:00	**Coffee Break** *15'*	
15:15	**Decomposing quark flavors via DVMP** *30'*	Speaker: Prof. simonetta liuti (university of virginia)
15:45	**Decomposing quark flavors via eta and pi0** *25'*	Speaker: Dr. Valery Kubarovsky (Jefferson Lab)
16:10	**Forward and backward BSA from pi+ pi0 and pi-** *25'*	Speaker: Diehl Stefan (UCONN)
16:35	**BSA from pi0 exclusive channel on 4He** *25'*	Speaker: Mr. Frank Cao (UConn)
17:00	**Group discussion** *20'*	

Common WG session
Thursday 8th 14:30 – 18:00:

- data quality and process status
- possible analysis synergies common to the whole Collaboration
- Common strategies
  strengthening the analysis quality and shortening the review time

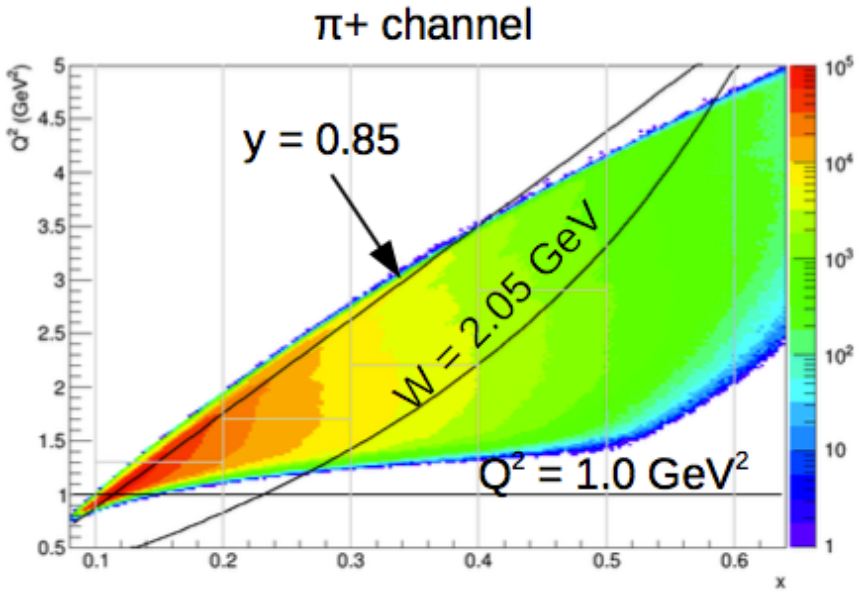
Update on E1-f SIDIS Analysis for Azimuthal Modulations*

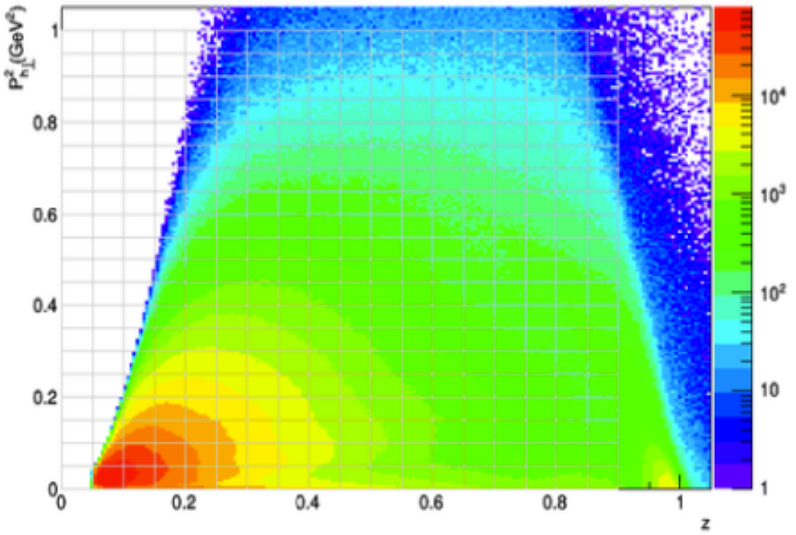
Nathan Harrison
UNG

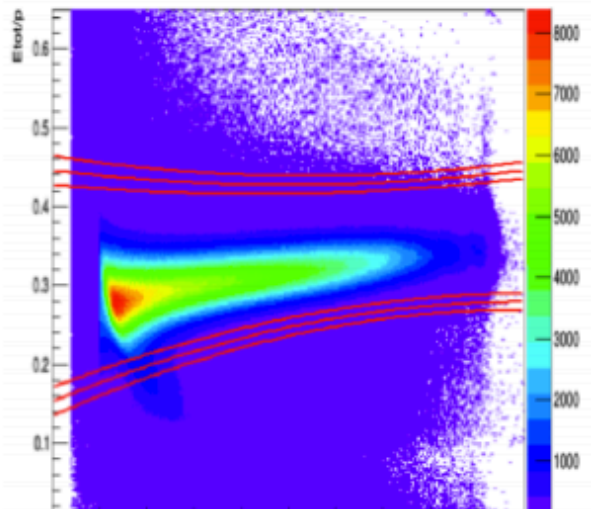
$$\frac{d^5\sigma}{dx\ dQ^2\ dz\ d\phi_h\ dP_{h\perp}^2} =$$

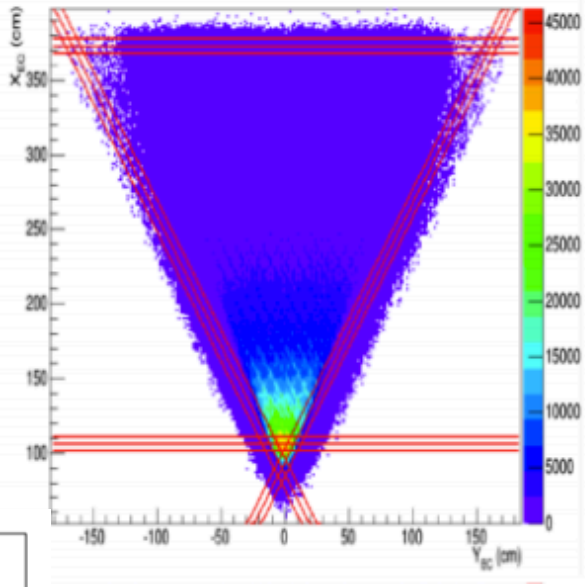
$$\underbrace{\frac{2\pi\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right)(F_{UU,T}+\epsilon F_{UU,L})}_{A_0}\left\{1+\underbrace{\frac{\sqrt{2\epsilon(1+\epsilon)}F_{UU}^{\cos\phi_h}}{(F_{UU,T}+\epsilon F_{UU,L})}}_{A_{UU}^{\cos\phi_h}}\cos\phi_h+\underbrace{\frac{\epsilon F_{UU}^{\cos 2\phi_h}}{(F_{UU,T}+\epsilon F_{UU,L})}}_{A_{UU}^{\cos 2\phi_h}}\cos 2\phi_h\right\}$$

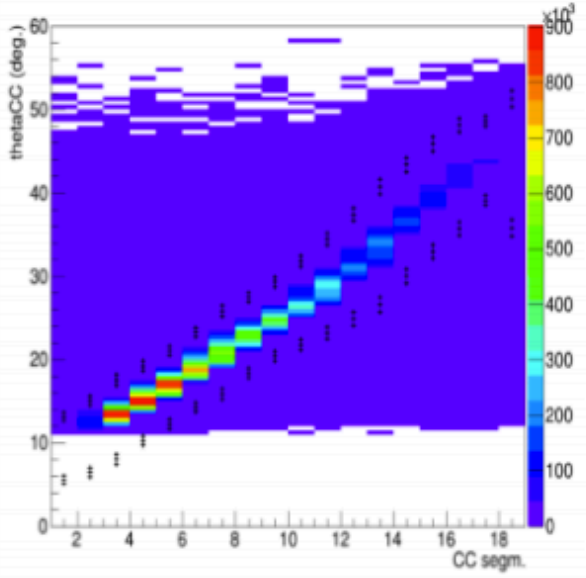
CLAS E1-f Data Set

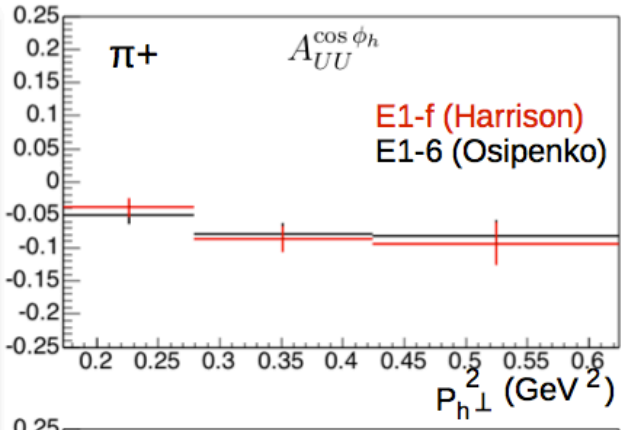


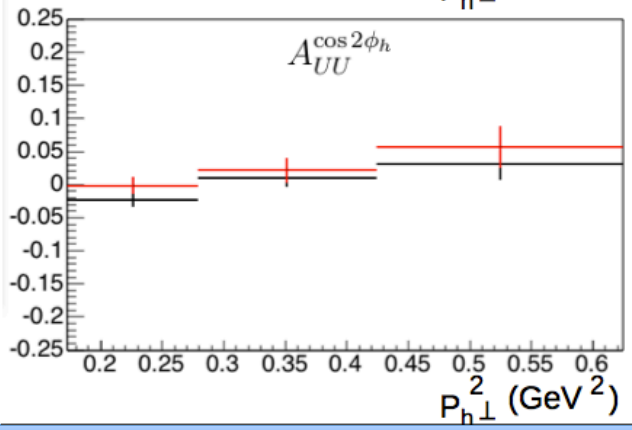


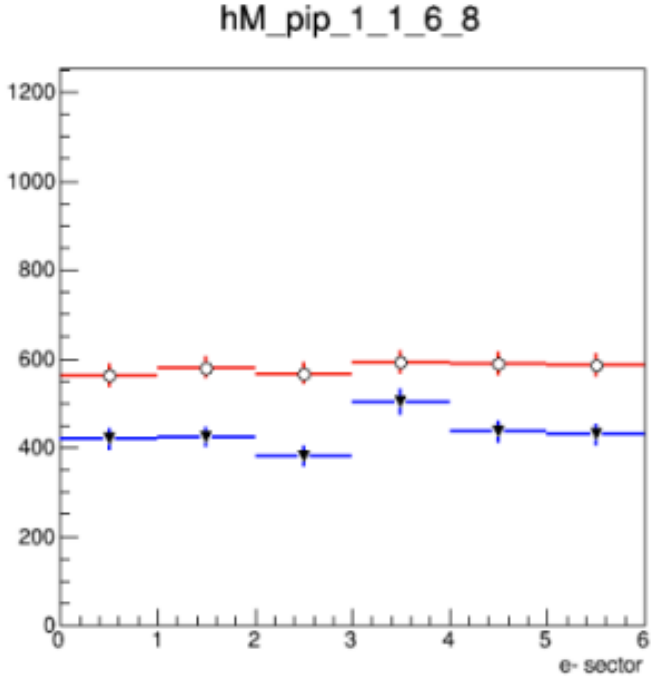



X_{EC} (cm)
Y_{EC} (cm)

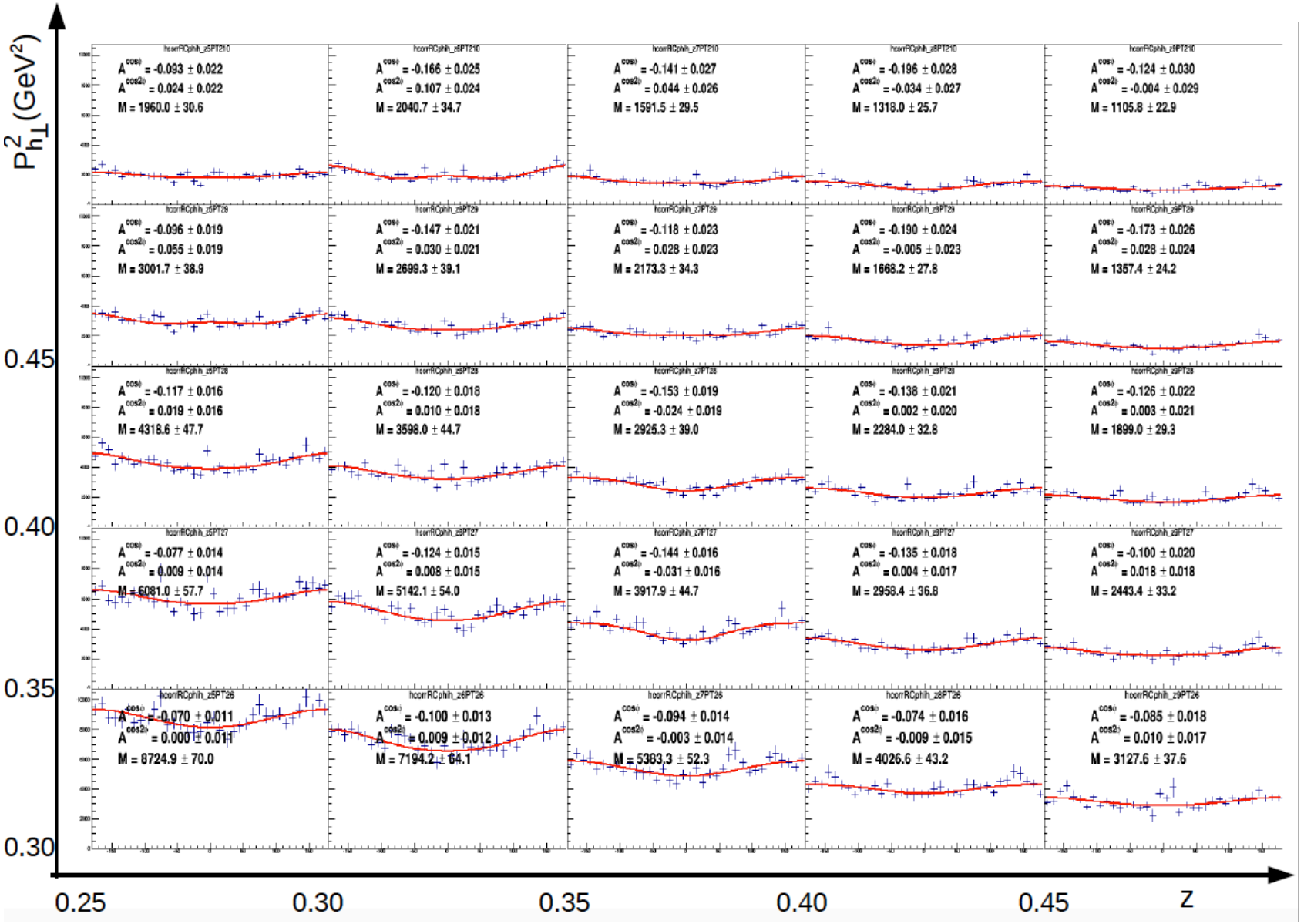

thetaCC (deg.)
CC segm.


π+
$A_{UU}^{\cos\phi_h}$
E1-f (Harrison)
E1-6 (Osipenko)
$P_{h\perp}^2$ (GeV^2)


$A_{UU}^{\cos 2\phi_h}$
$P_{h\perp}^2$ (GeV^2)


hM_pip_1_1_6_8
e- sector

Analysis recently approved, paper in preparation for PRL



Beam Spin Asymmetries for Positively Charged Kaons

David Riser, University of Connecticut
in collaboration with Kyungseon Joo, Nick Markov

$$F_{LU}^{\sin\phi} = \frac{2M}{Q}\mathcal{C}\left(-\frac{\hat{\mathbf{h}}\cdot\mathbf{k_T}}{M_h}\left(xeH_1^{\perp} + \frac{M_h}{M}f_1\frac{\tilde{G}^{\perp}}{z}\right) + \frac{\hat{\mathbf{h}}\cdot\mathbf{p_T}}{M}\left(xg^{\perp}D_1 + \frac{M_h}{M}h_1^{\perp}\frac{\tilde{E}}{z}\right)\right)$$

twist-3 pdf

Collins FF

unpolarized dist. function

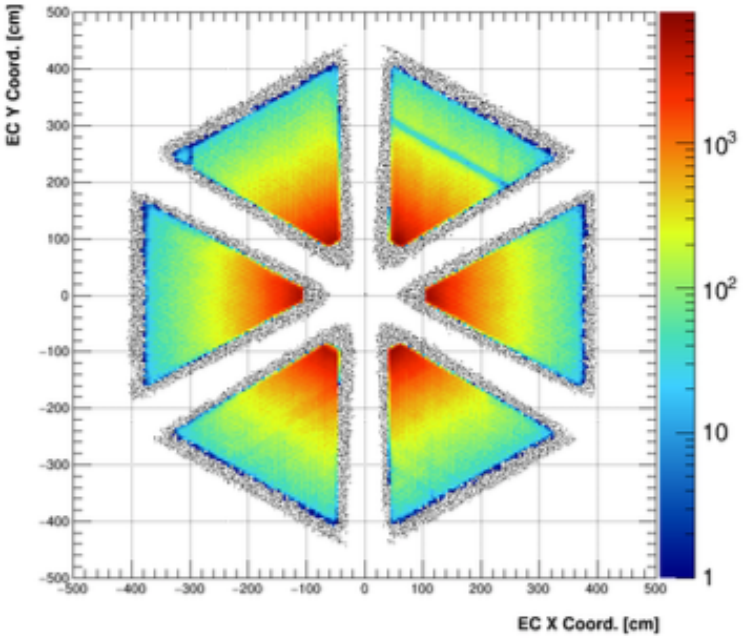
twist-3 FF

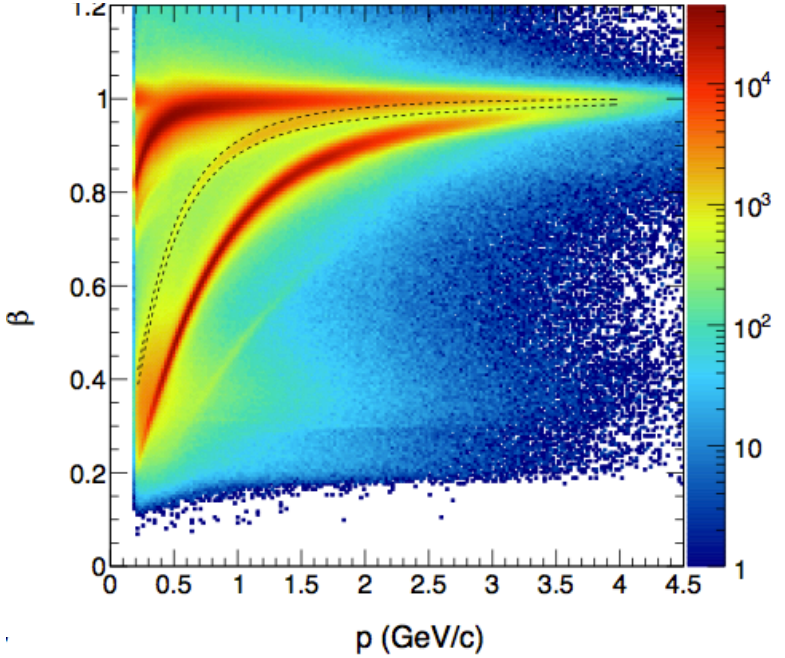
twist-3 t-odd dist. funcion

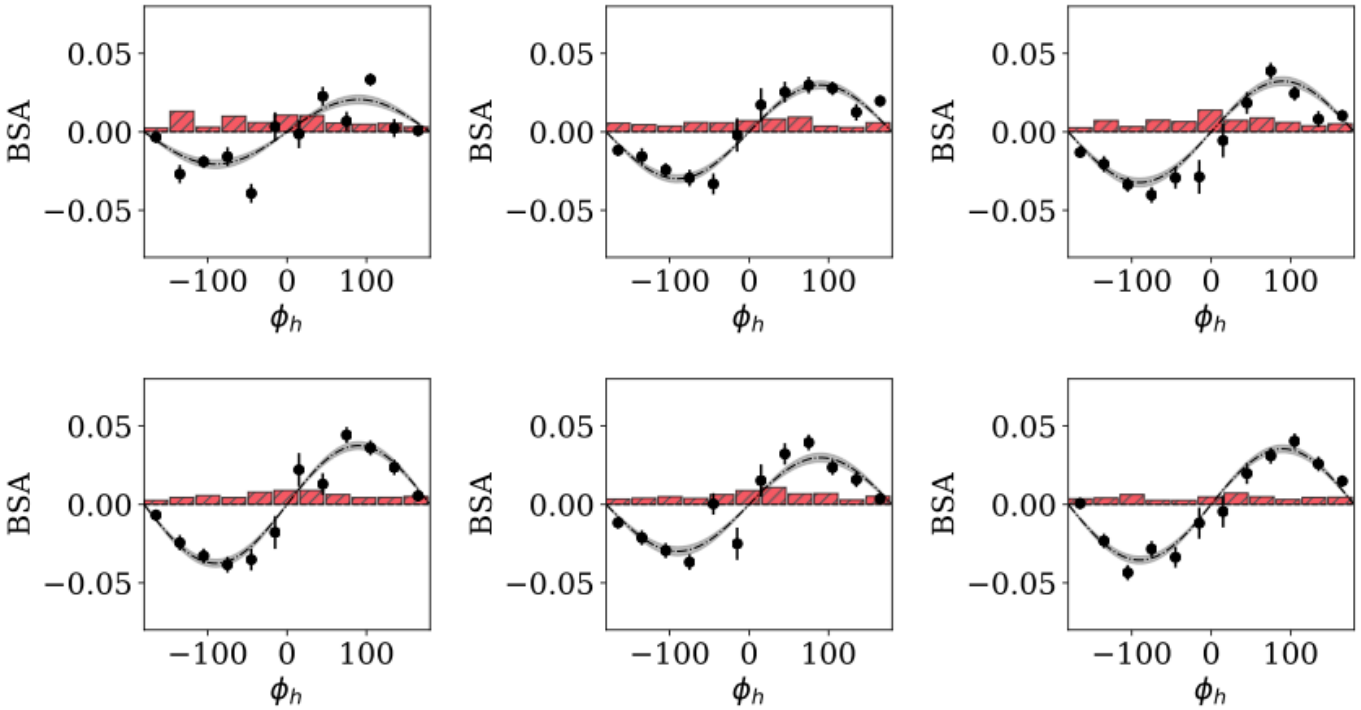
Boer-Mulders

twist-3 FF

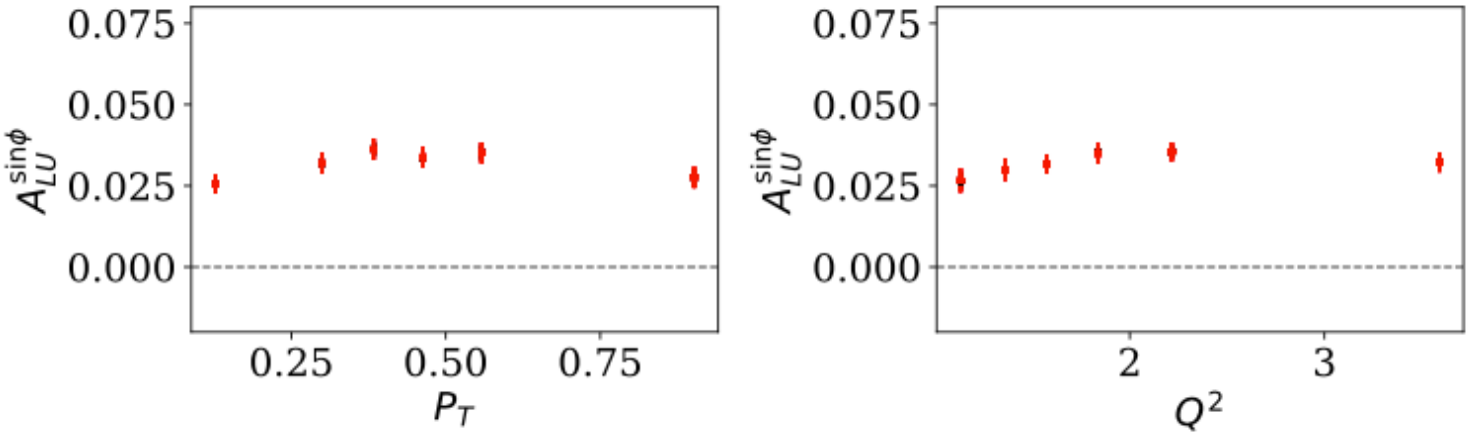
Run period: E1-F







Shown above: Different x bins.



DVCS status

François-Xavier Girod
Guillaume Christiaens
Joshua Artem Tan
Maxime Defurne
Latifa Elouadrhiri

$$ep \rightarrow ep\gamma$$

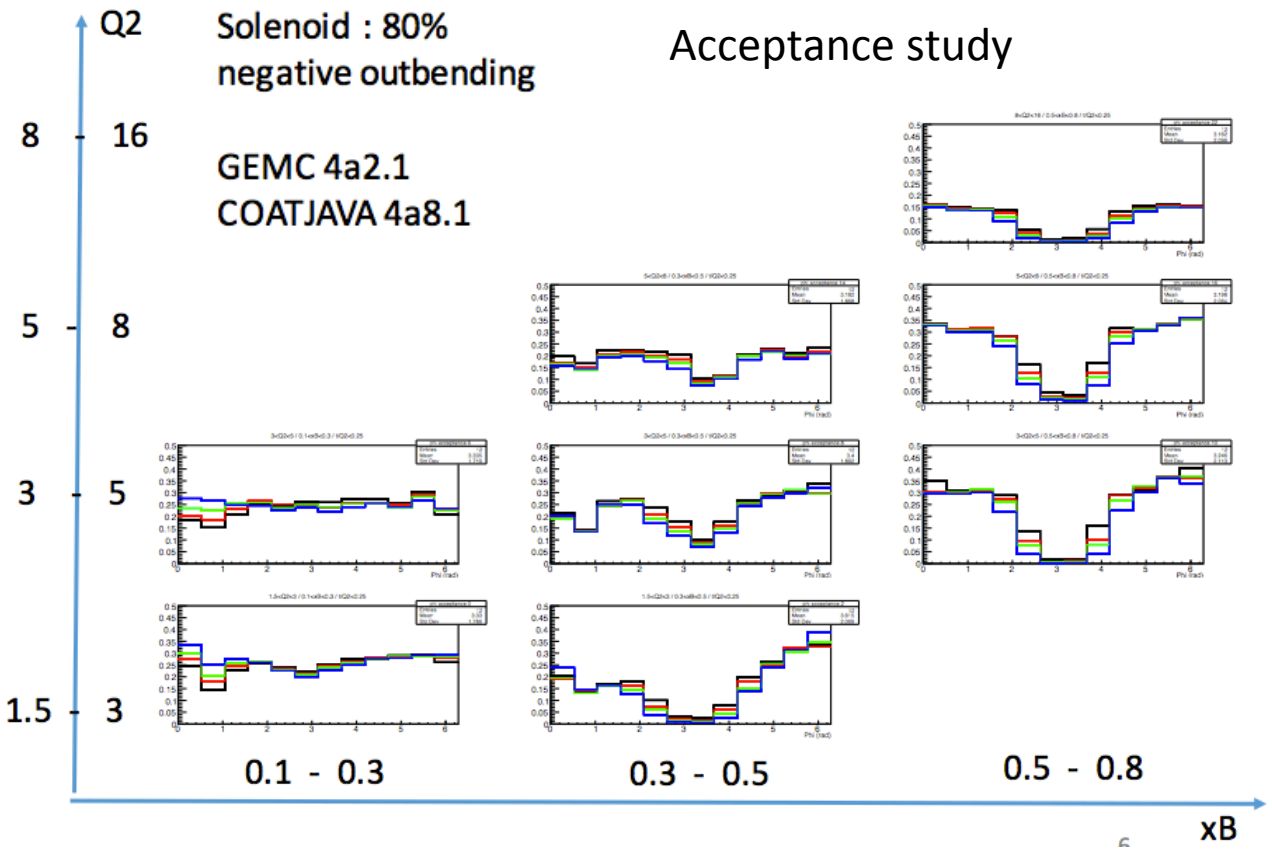
- Golden channel for GPD measurement

Q2

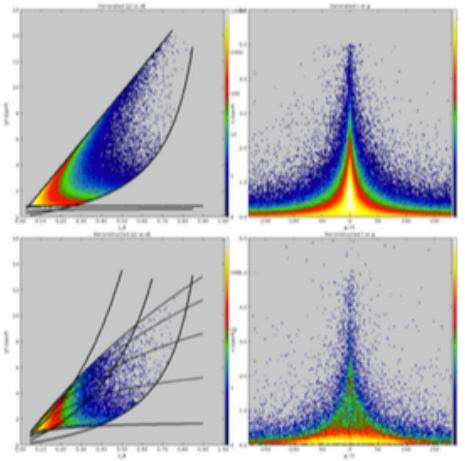
Solenoid : 80%
negative outbending

GEMC 4a2.1
COATJAVA 4a8.1

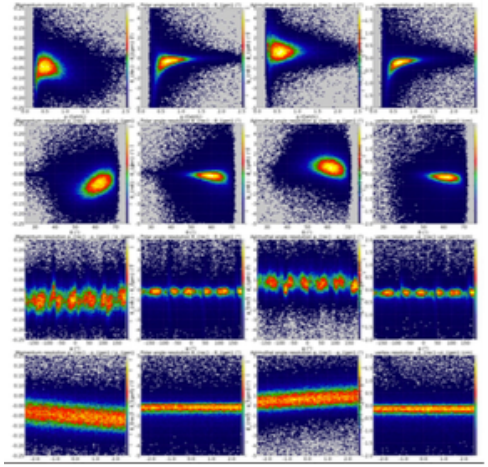
Acceptance study



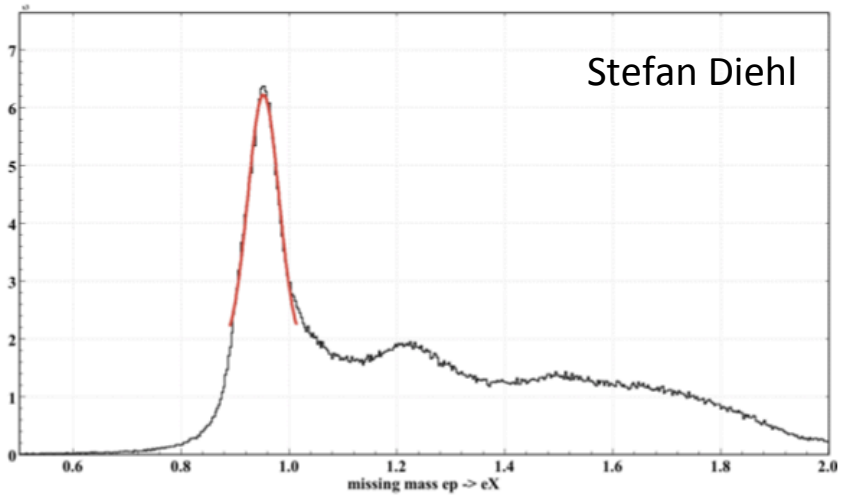
Kinematical variables



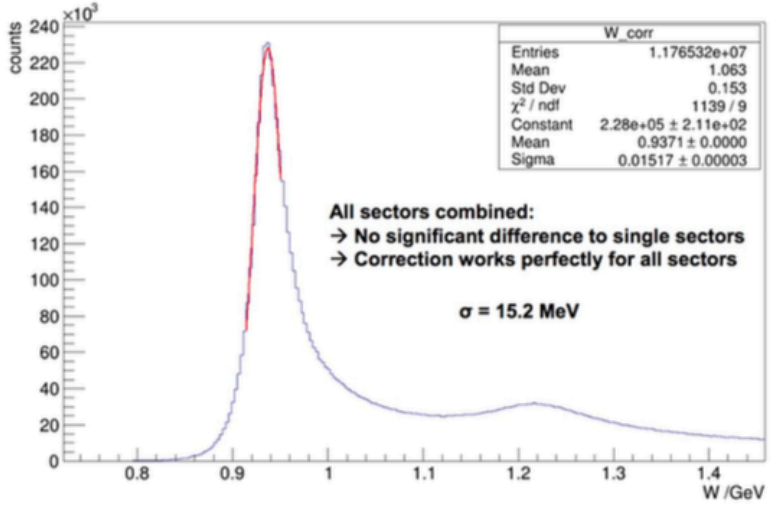
Proton Resolutions



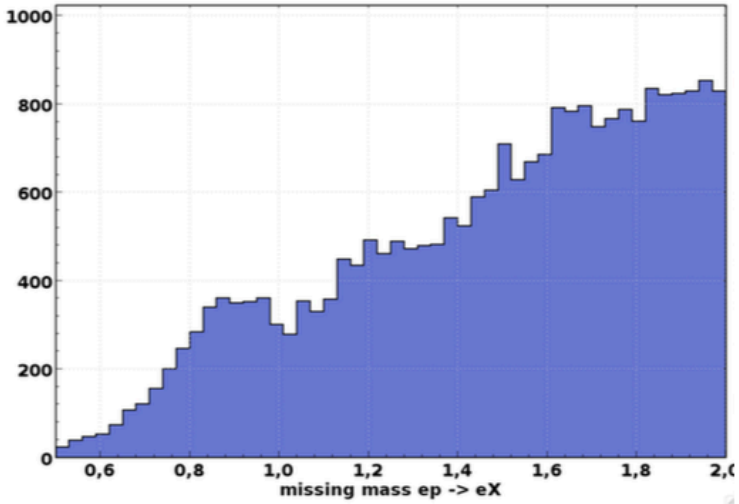
Data – Elastic 2.2 GeV



Run 2475, solenoid +0.6%, torus +0,6%, 2nA



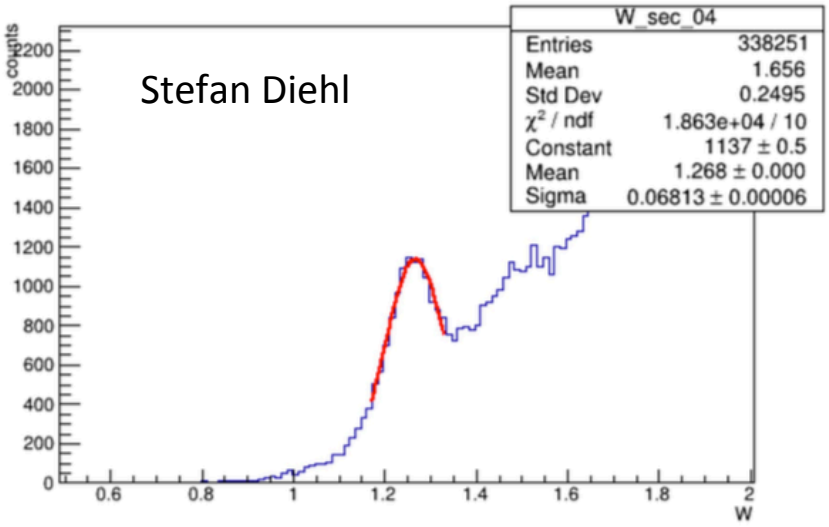
Data – Elastic 6.4 GeV



Sector 4 without cuts and without corrections

Run 3105, solenoid -100%, torus +0,75%, 10nA

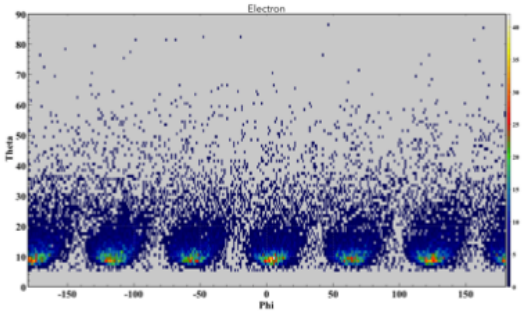
W sector 4

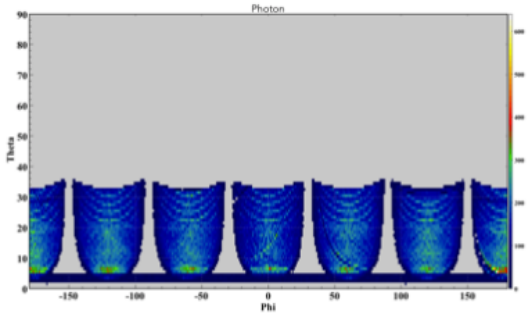


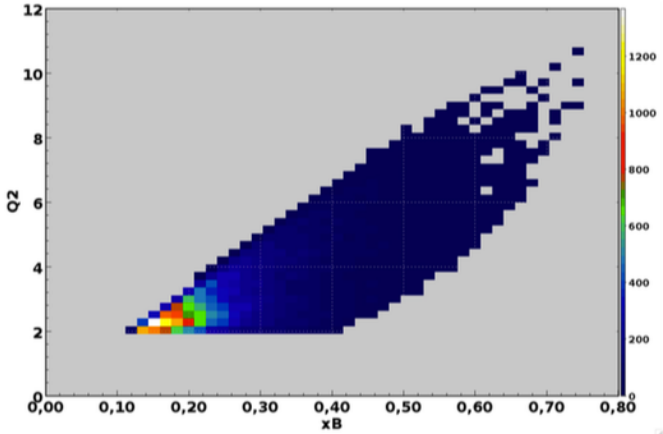
Sector 4 with additionnal cuts (old software version)

Run 3105, solenoid -100%, torus +0,75%, 10nA

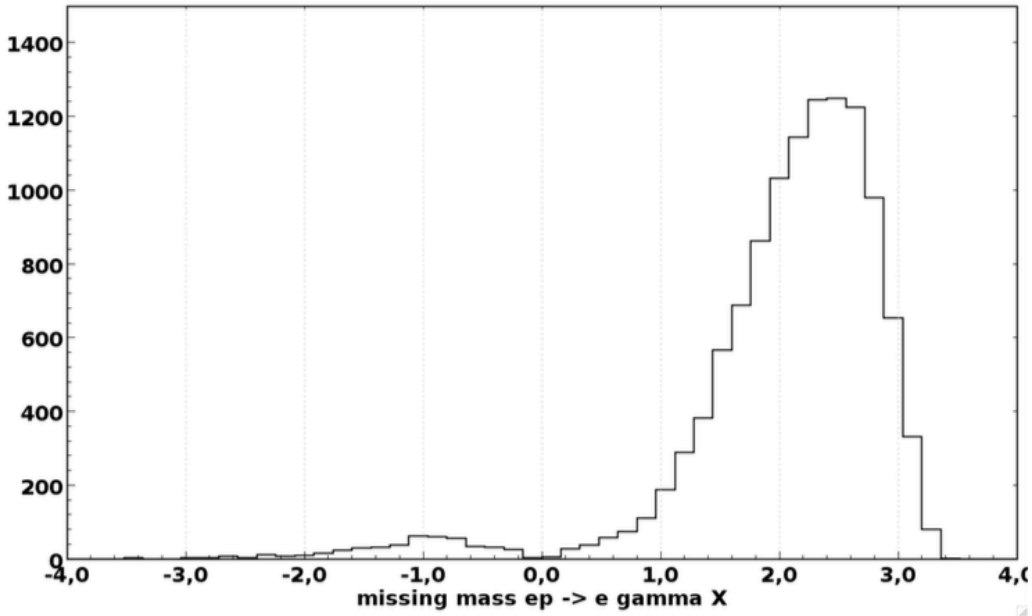
Data – 11 GeV Kinematic







- Run 3432
- -100% Solenoid / -100% Torus, 50 nA
- Peak not strong enough, too wide or at the wrong location
- Work on tracking and alignment is critical
- Work on magnetic field map will help a lot



Status of the neutron-DVCS/BH simulation at CLAS12

Rong Wang, Pierre Chatagnon, Silvia Niccolai…
Institut de Physique Nucléaire d'Orsay, France

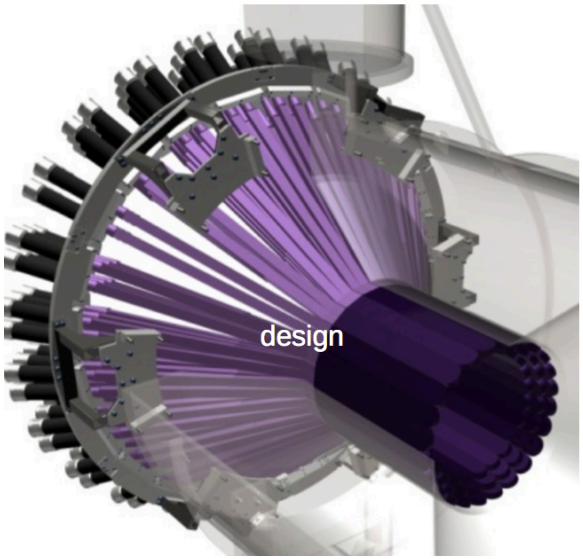
Access to GPD E (via BSA) + flavor separation

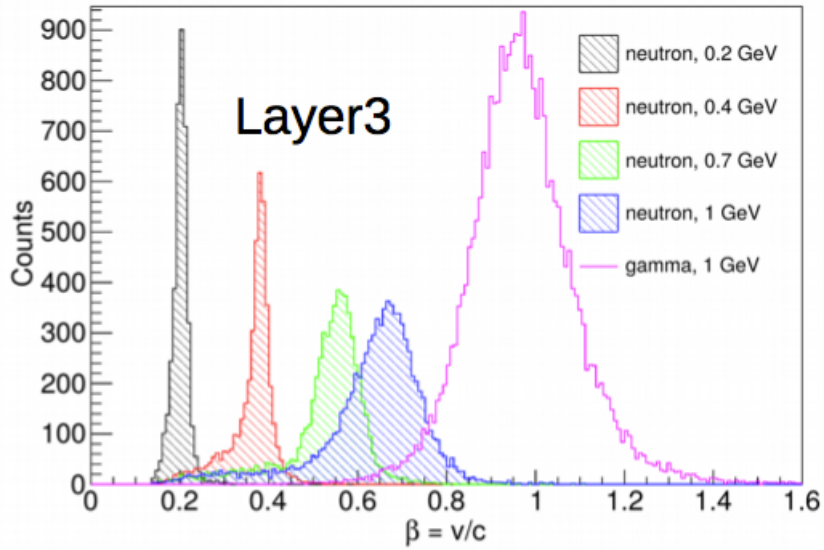
$$J_q = \frac{1}{2}\int_{-1}^{1} dx x[H^q(x,\xi,t=0) + E^q(x,\xi,t=0)]$$

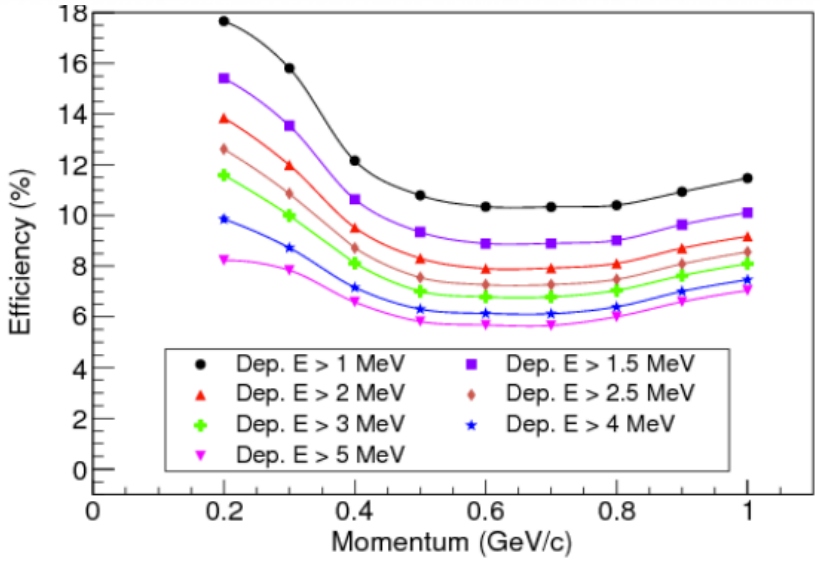
genepi (event generator based on VGG model)

+ gemc (4a.2.2)

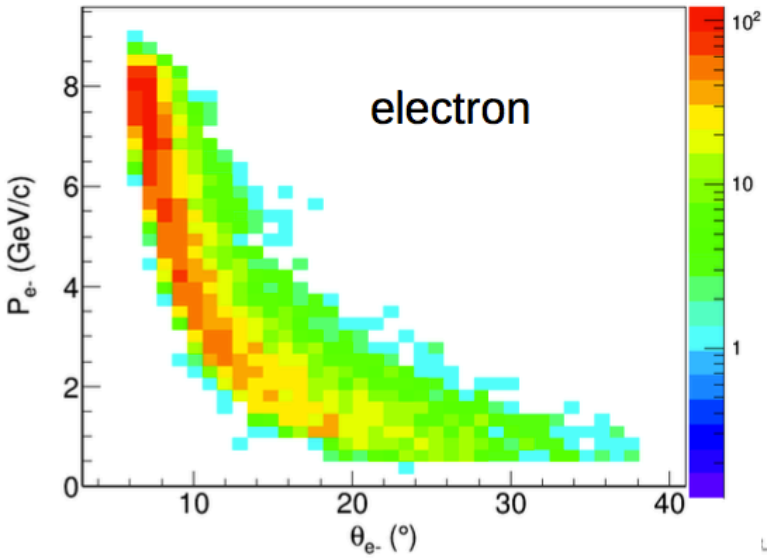
+ coatjava (5a.0.19)

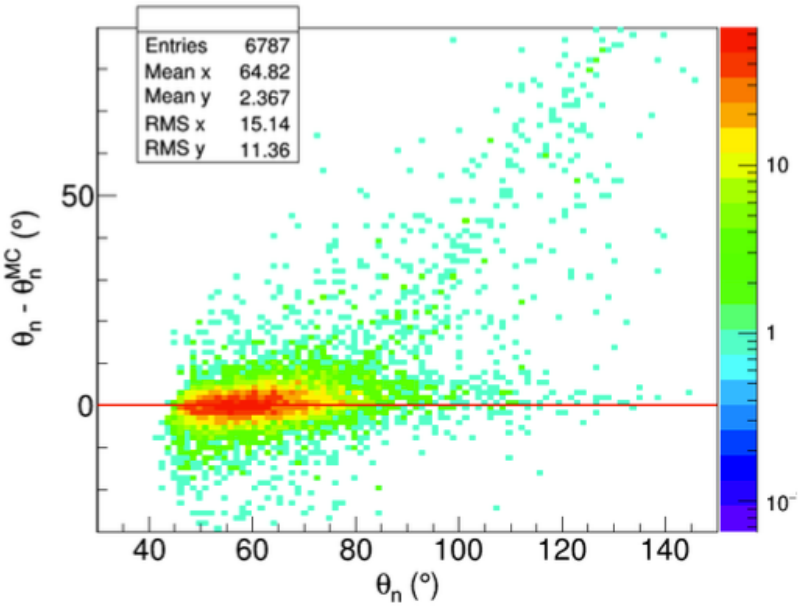


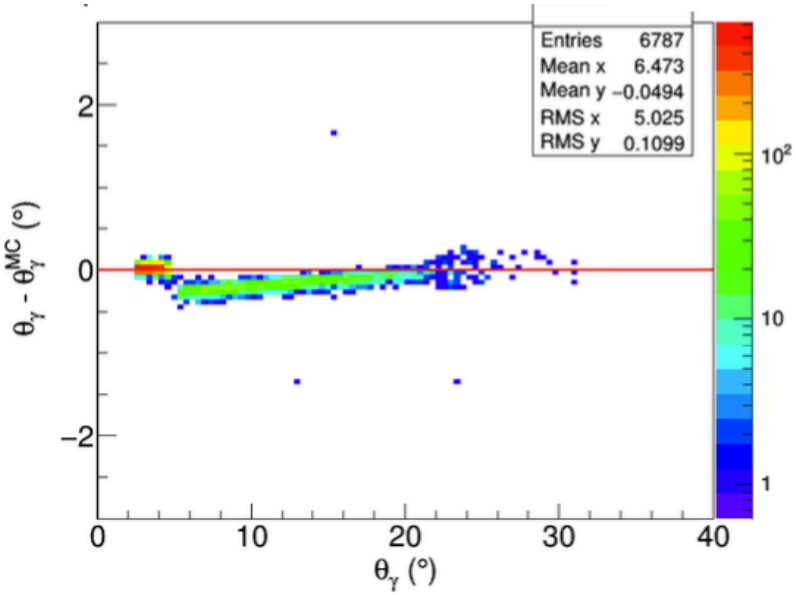


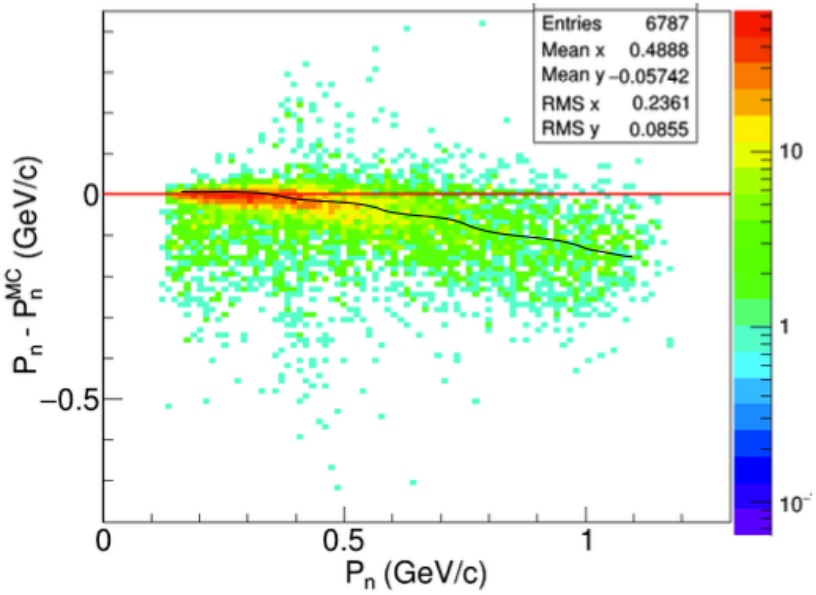


n-DVCS: reconstructed final state particles

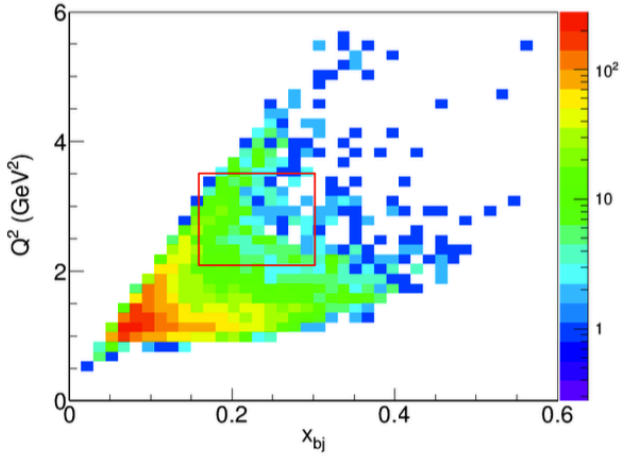


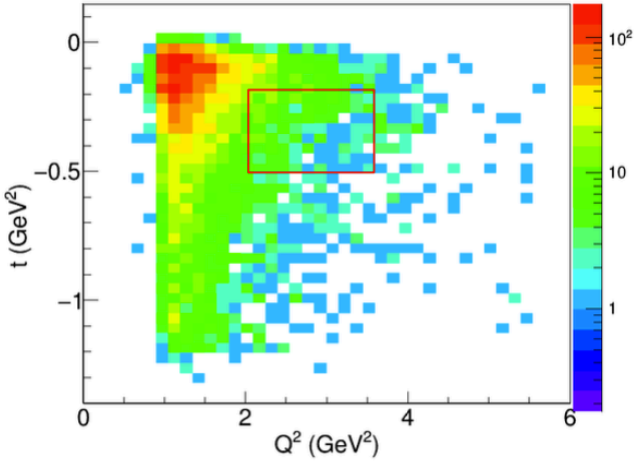


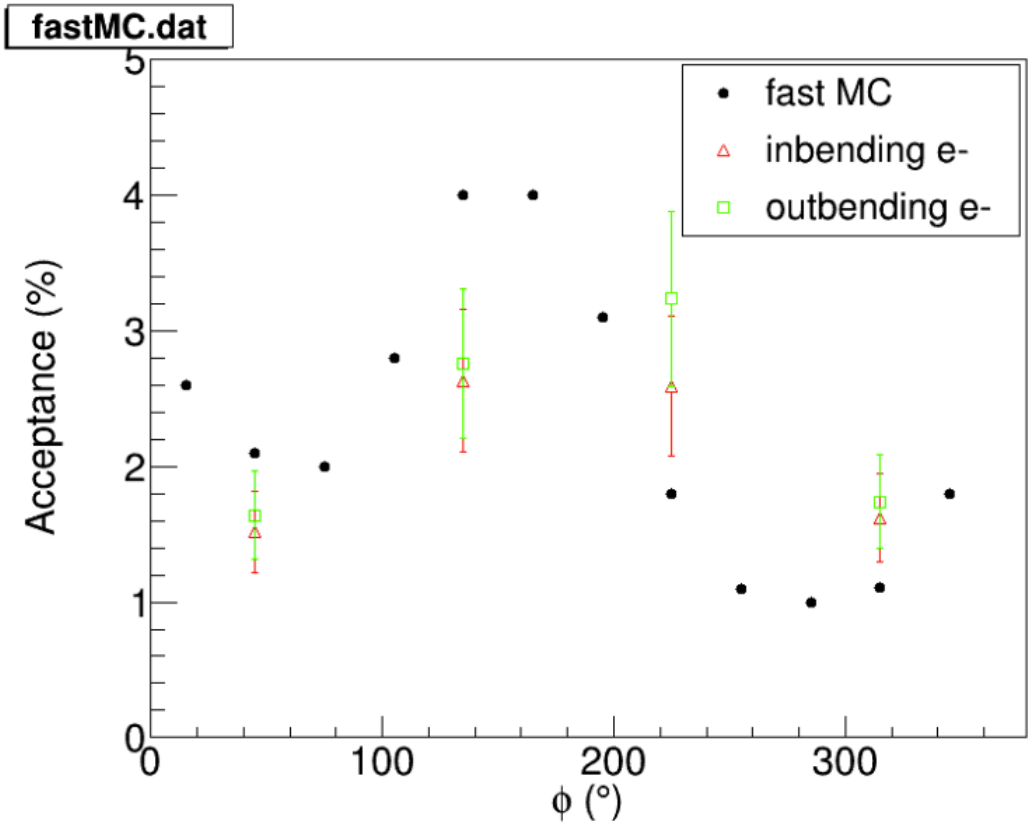




n-DVCS: acceptance



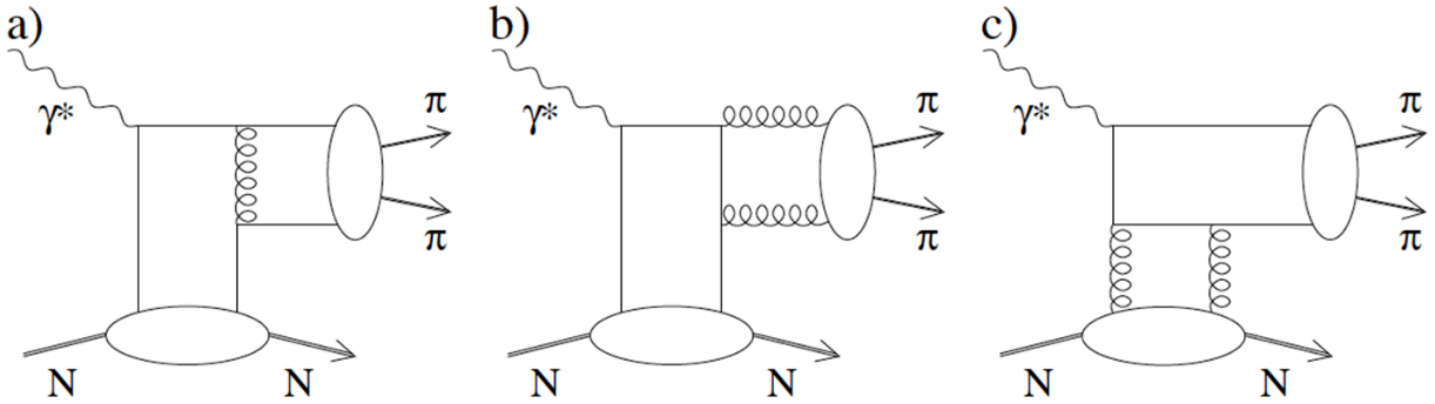




Deep Virtual Production of Pion Pairs

Dilini Bulumulla
Old Dominion University

- Leading order diagrams for exclusive deep virtual production of two pions



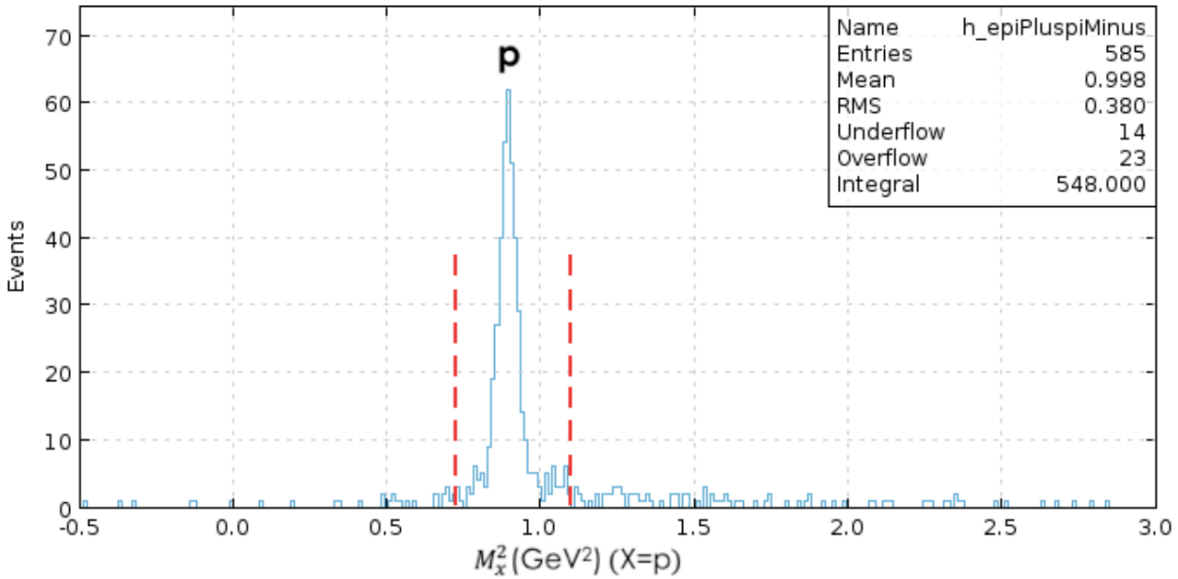
- $ep \rightarrow e'p'\pi^+\pi^-$
  - Isospin I=1, angular momentum J=1
    - $\rho(770)$
  - Isospin I=0, angular momentum J=0
    - $f_0(500) = \sigma, f_0(980)$
- $ep \rightarrow e'p'\pi^0\pi^0$
  - Isospin zero, spin zero channel (I:J=0:0)
    - $f_0(500) = \sigma, \quad f_0(980)$

- Microscopic structure of $f_0(500)$ not well understood.
  - $q\bar{q}$: $^3P_0$
  - Tetraquark
  - $\pi\pi$ -molecule
  - Glueball
  - Superposition of all of the above
- Deep sigma-production offers intriguing evidence for gluonic content of $f_0(500)$.

- **Monte-Carlo Generation of Phase Space Variables**
  - There are eight independent kinematic variables in the final state of the $ep \rightarrow e'p'\pi\pi$ reaction.
  - $Q^2, x_B, \phi_e, M_{1,2}^2, t, \phi_{1,2}^*, cos\theta_{\sigma\_Rest}, \phi_{\sigma\_Rest}$

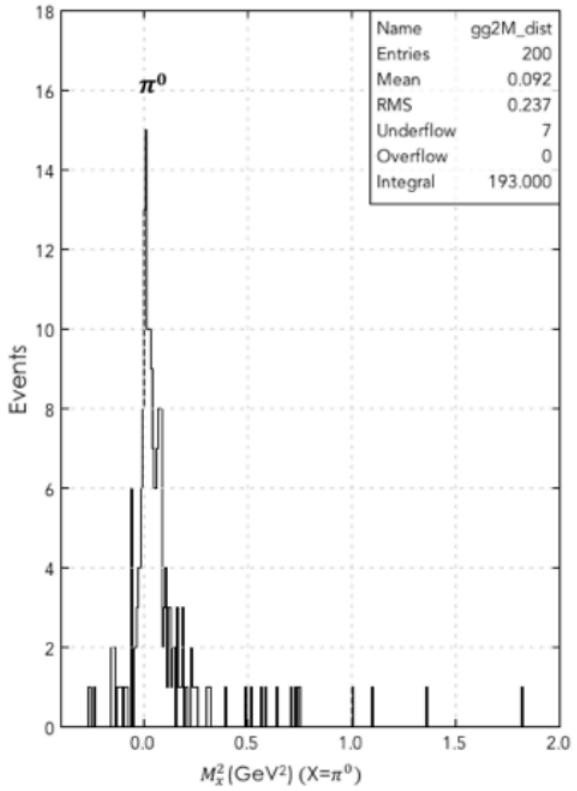
GEMC version 4a.2.1
COATJAVA version 4a.8.2

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



Detection ⊗ reconstruction efficiency ≈ 8%

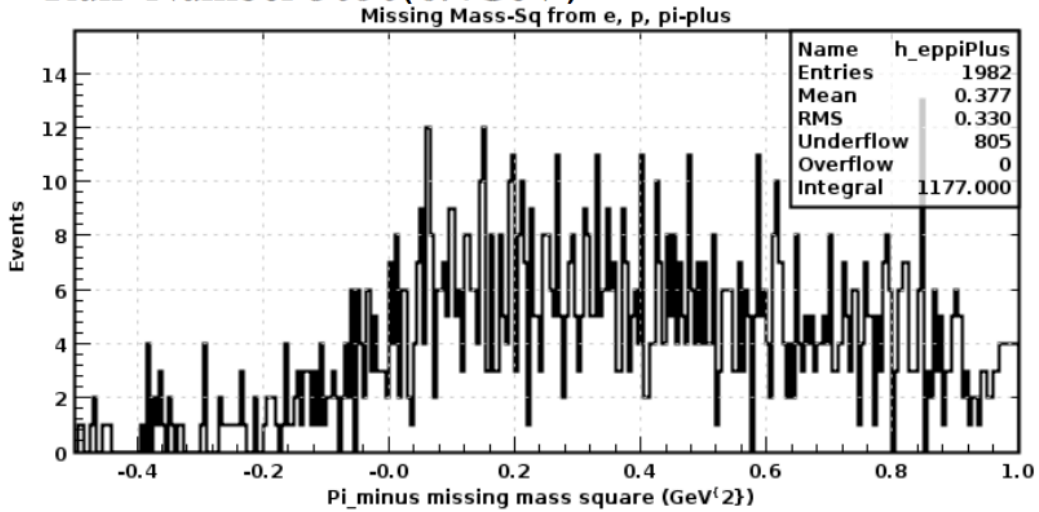
$ep \rightarrow e'p'\pi^0X$



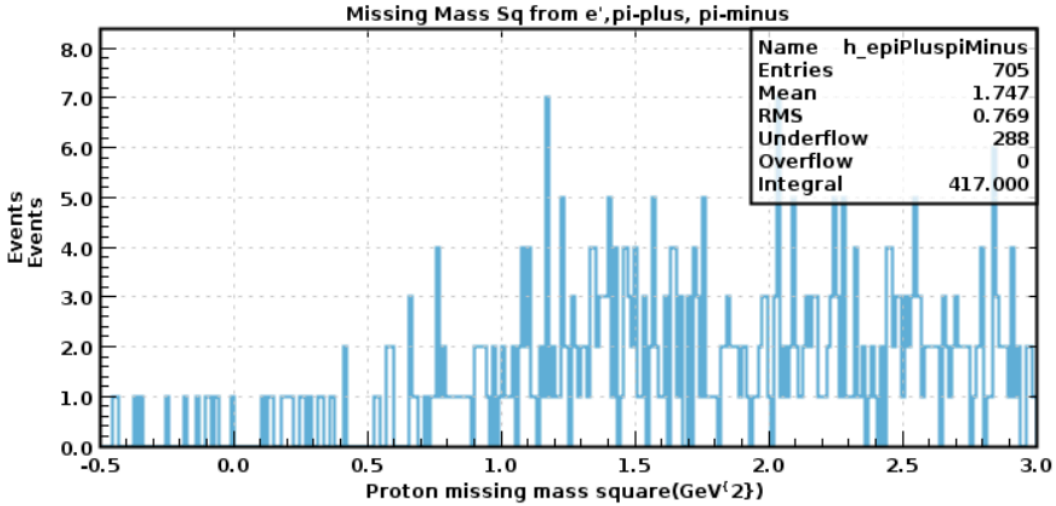
Detection ⊗ reconstruction efficiency ≈ 2%

Real Data Analysis

- Run Number 3050(6.4GeV)



- Missing mass square of π^-



- Missing mass square of Proton

Thresholds look physical, but no sign of an exclusive peak in any of the three channels

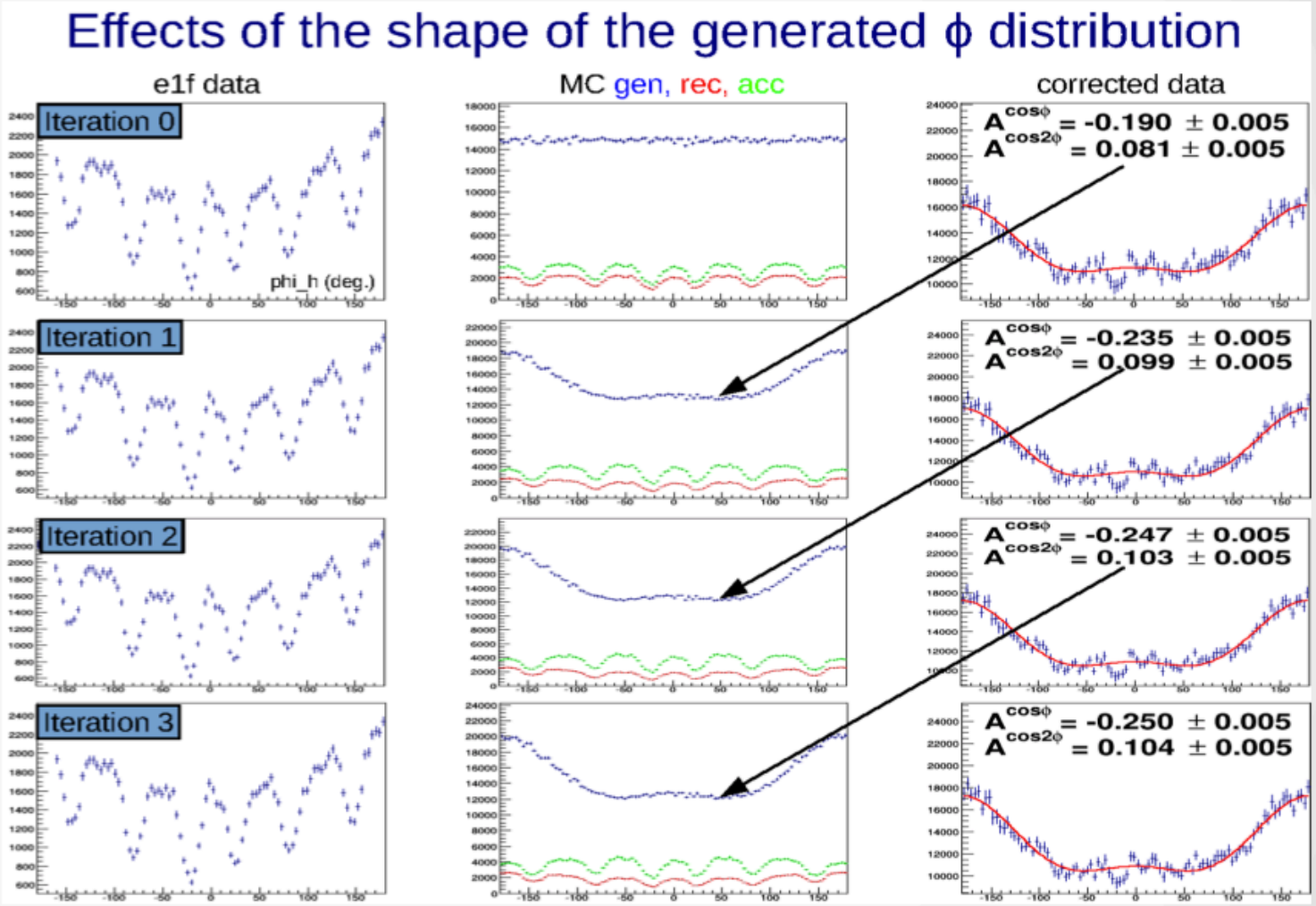
- Particle ID?
- Momentum Calibrations?

Acceptance Corrections: Bin-by-Bin Method vs. Matrix Conversion Method

Kyungseon Joo | Nikolay Markov, Brandon Clary | University of Connecticut

Iterative Unfolding using Bin-by-Bin Method

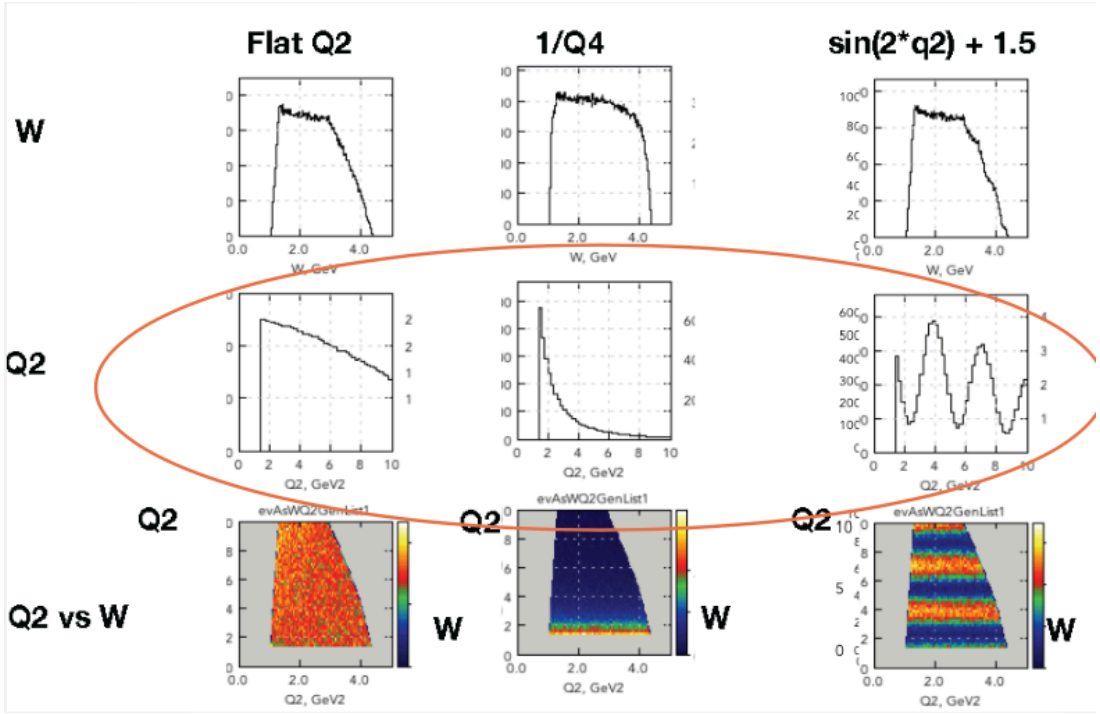
N. Harrison PhD Thesis for pion SIDIS

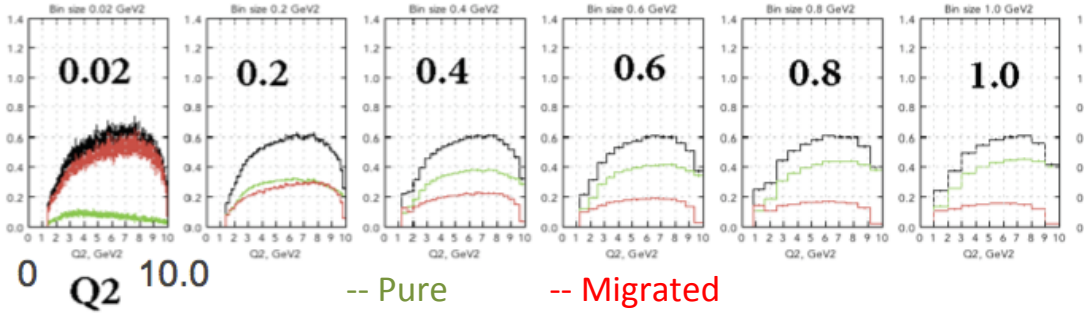


2. Matrix Method

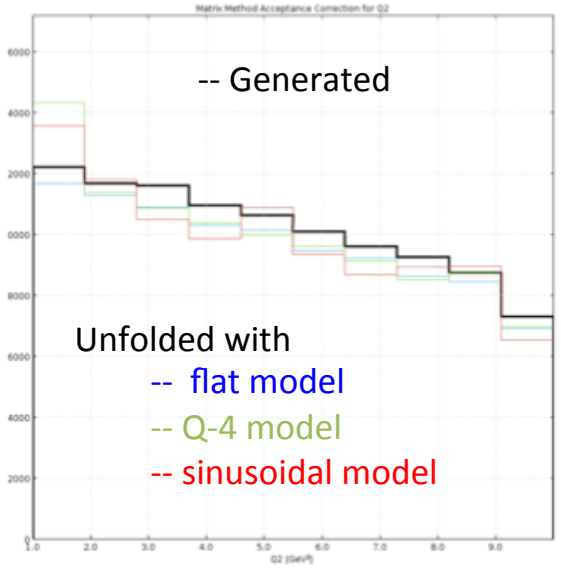
$$D_i = \sum M_{ij} T_j + B_i \qquad M_{ij} = N_i^{REC} / N_j^{GEN}$$

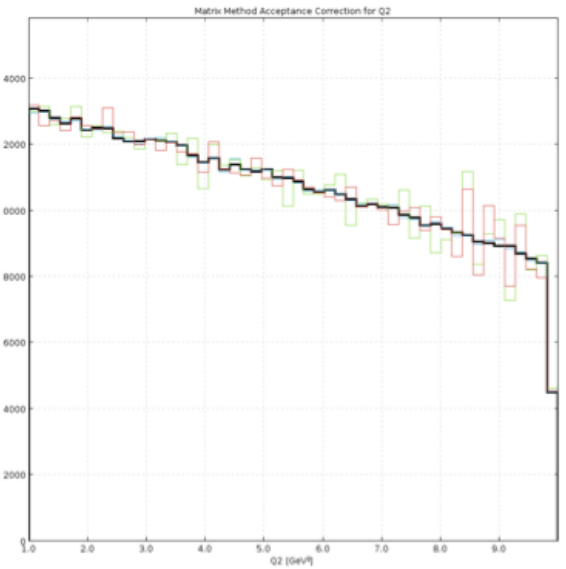
M_{ij} is the acceptance matrix





-- Pure -- Migrated

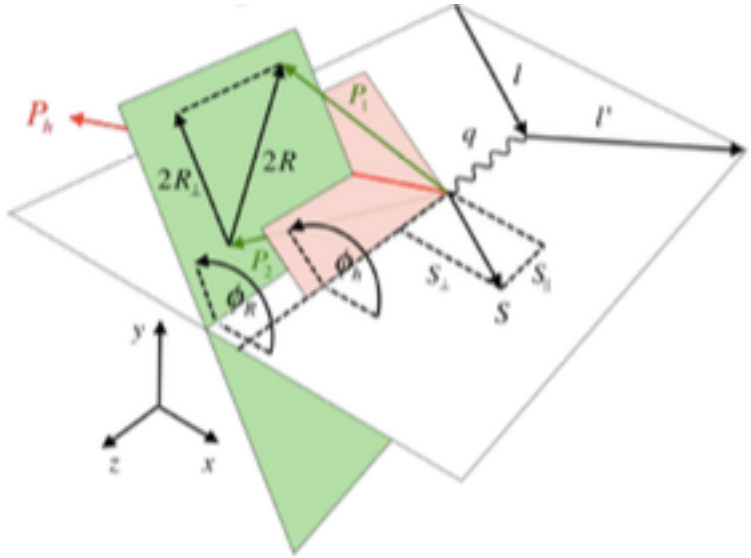


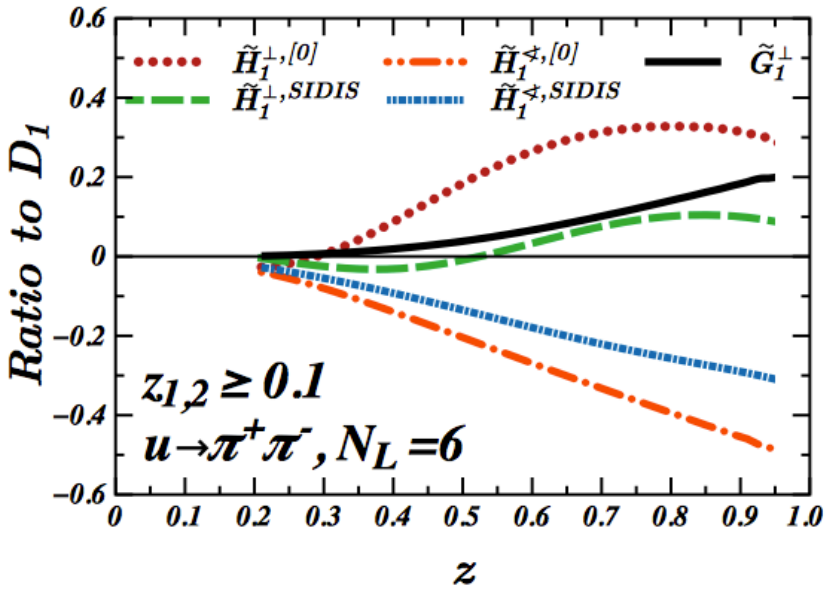


Di-hadron and other plans at CLAS

Anselm Vossen

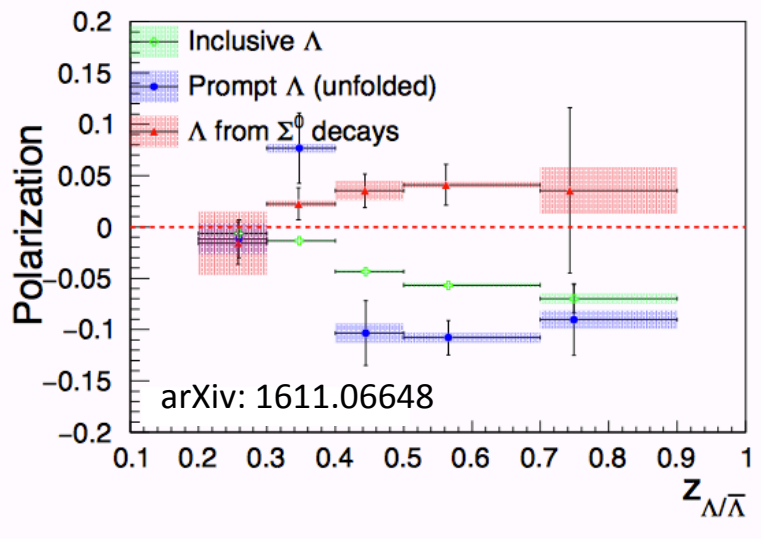
- Formalism very similar to single hadron FF
- Additional degree of freedom (P_1-P_2=R)
- Relative momentum of hadrons can carry away angular momentum
  - Partial wave decomposition in θ
  - Relative and total angular momentum →In principle endless tower of FFs
  - Analogue of 1h production with spin in final state
- Makes 'new' FFs possible, such as $G_1^{\perp}$: T-odd chiral even. In 1h case, this needs polarized hadron in the final state

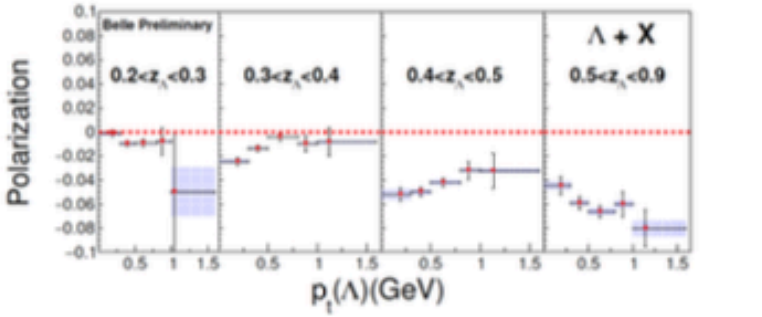


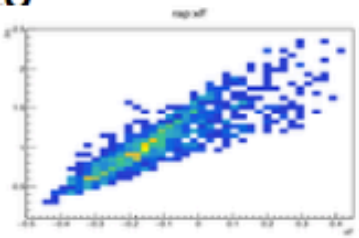


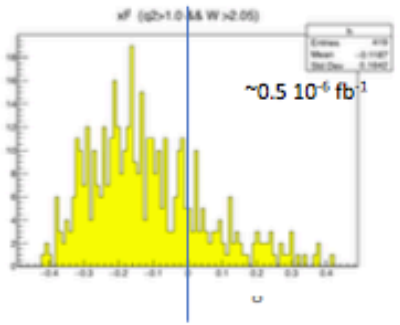
Lambda's

- Can we do current Λs?
- From simple Pythia simulation using just geometric CLAS acceptance, it seems there is a fair amount of $x_F > 0$ (but Berger $\Delta\eta>2$ seems not feasible)
- Would open up many physics topics
- Example, compare with $\Lambda^{\uparrow}$ production in e+e- (Boer, Kang, Vogelsang, Yuan,PRL. 105 (2010) 202001, learn about TMD factorization
- Can we expect the feed-down contribution to be the same?



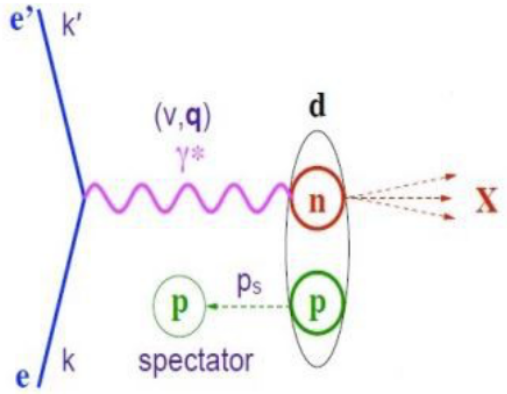


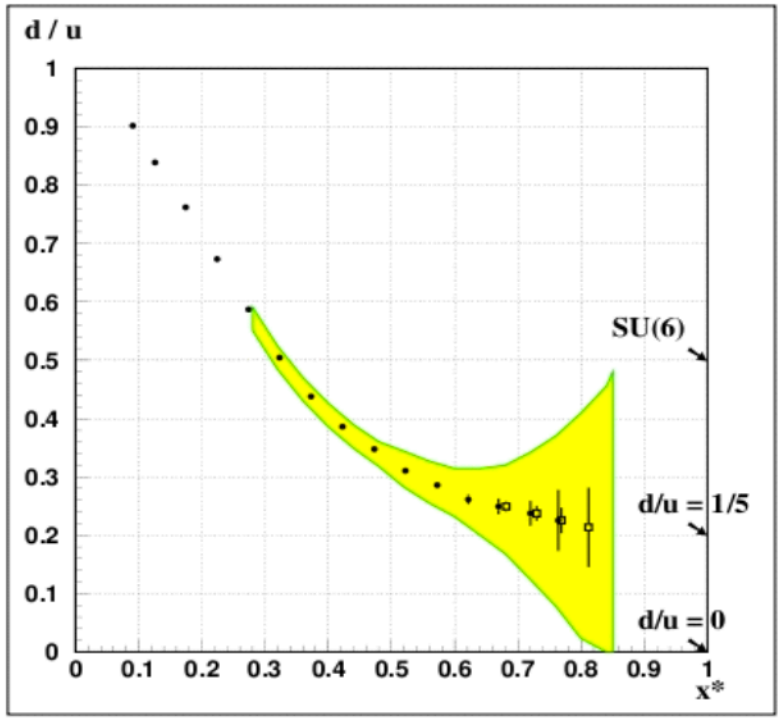




Preparations for BONuS12 experiment

Aruni Nadeeshani
Hampton University

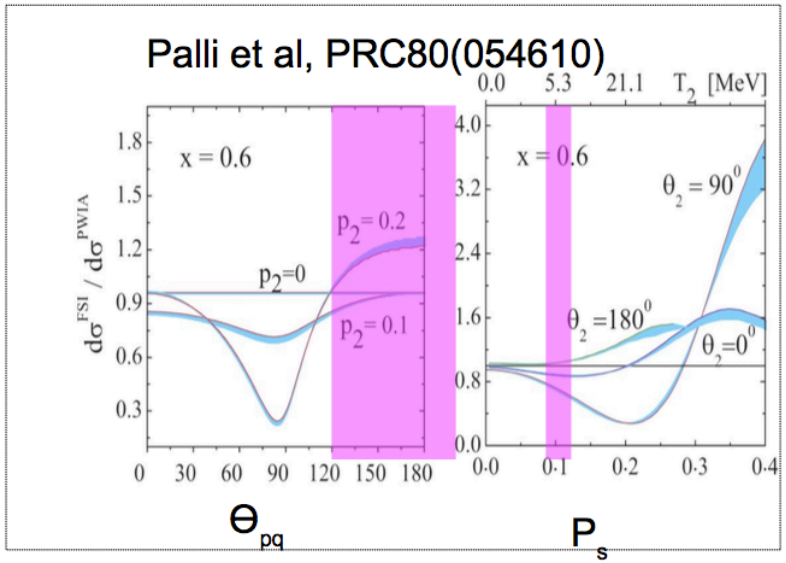




- Selecting backward, low momentum spectator protons minimizes:

  -Off shell effects

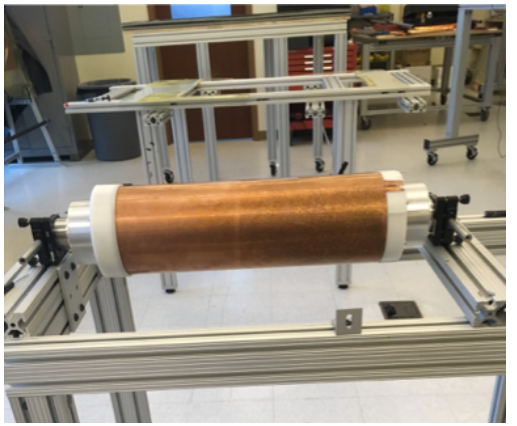
  -Final state interactions

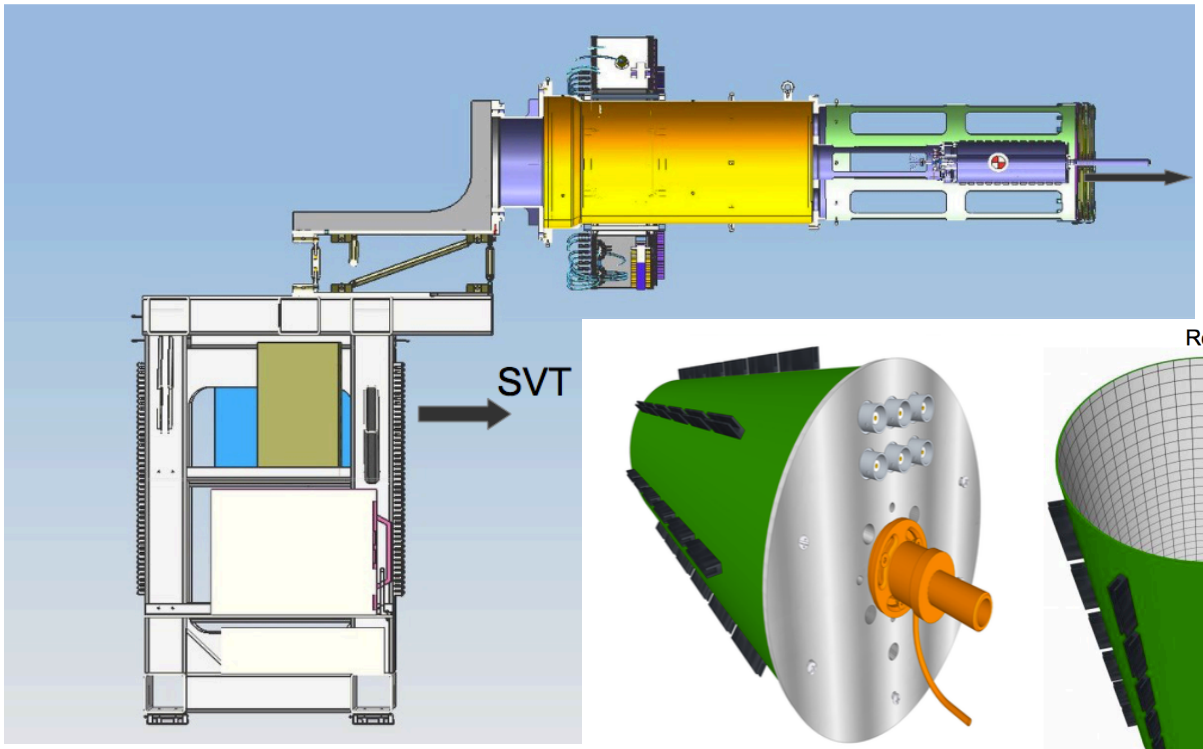


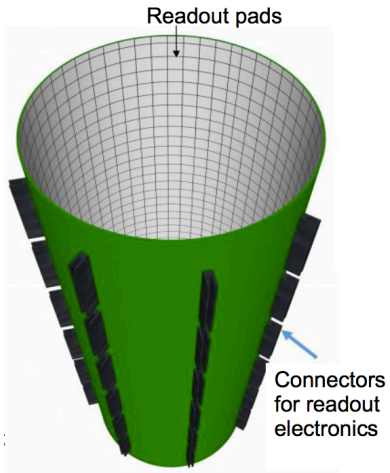
BONuS12 RTPC

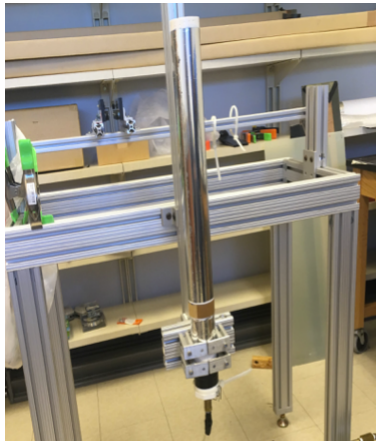
Construction by Oct 18
Ready to run in 2019

- Improvements over BONuS6
- Double RTPC and target length ->increase luminosity to $2x10^{34}$ $cm^{-2}s^{-1}$.
- Increase drift region from 3 cm to 4 cm ->improve momentum resolution
- Reduce material and better reconstruction algorithm -> lower threshold momentum of proton.
- Increase phi acceptance.





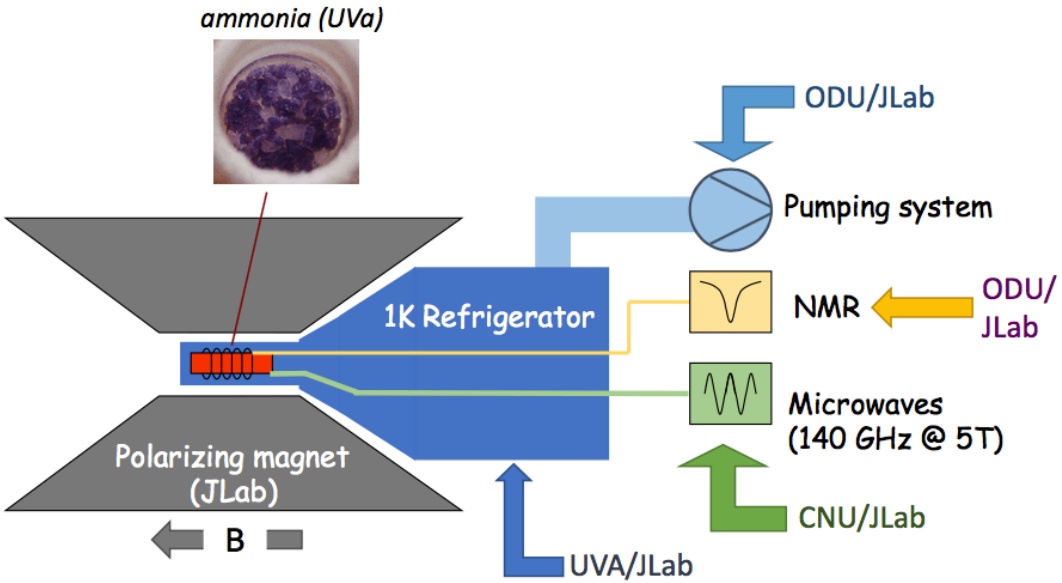




Update on the Longitudinally Polarized Target

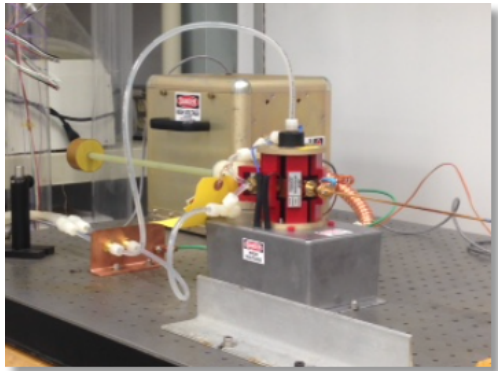
Chris Keith
Jefferson Lab Target Group

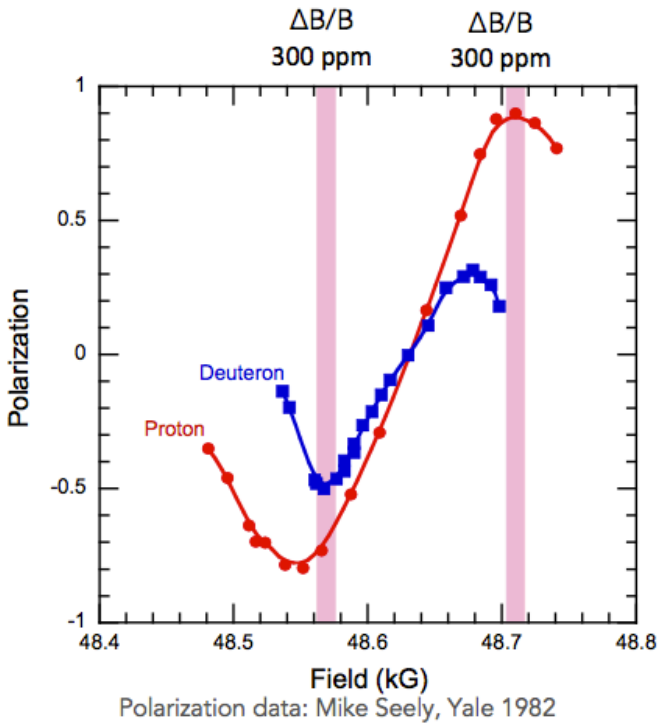
(w/ James Brock, Chris Carlin, James Maxwell & Victoria Lagerquist)



ODU 6000 m^3/h pumping set

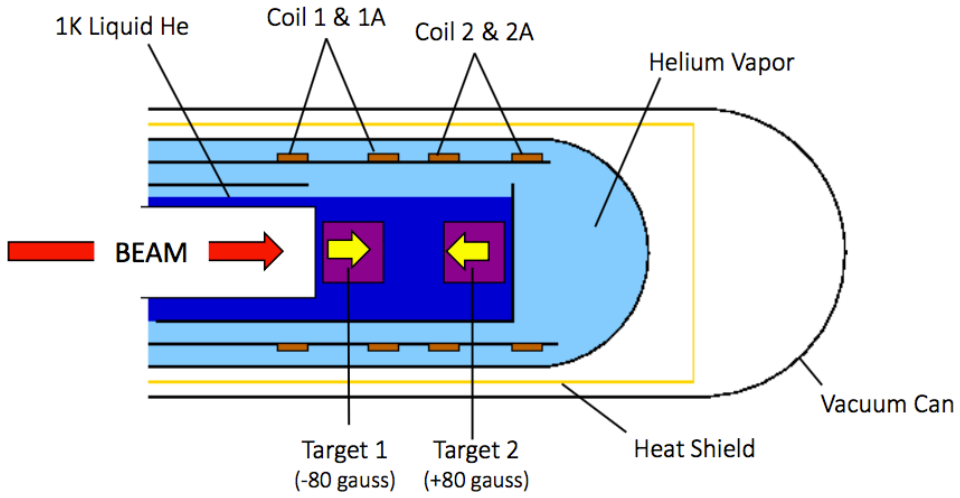
CNU 135 GHz microwave tube

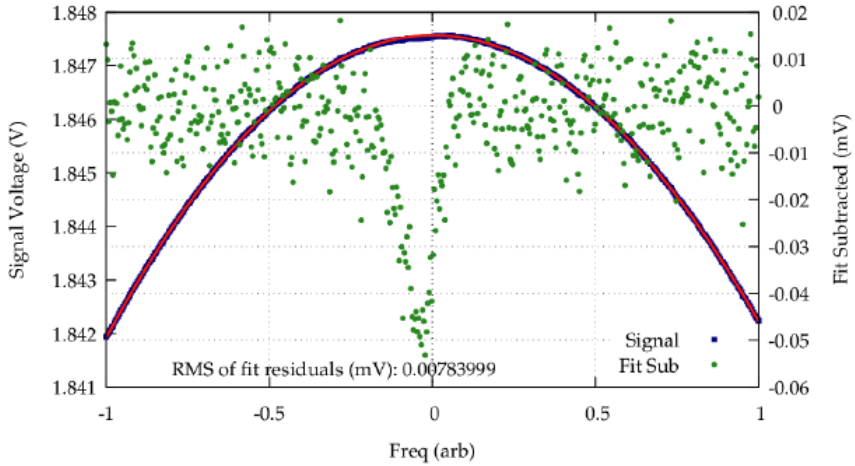


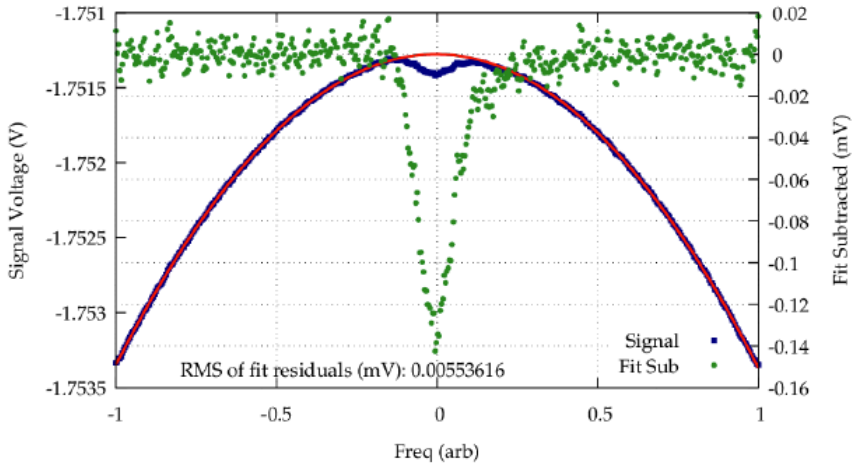


Polarization data: Mike Seely, Yale 1982

We can adjust the CLAS12 field with ± 80 gauss shim coils and simultaneously polarize two samples in opposite directions.







Traditional circuit @ 77 K, 5 T NMR New circuit @ 77 K, 5 T

- Polarized NH3/ND3 target under construction for Run Group C
- Most instrumentation is in hand (already at JLab)
- One major component is currently under construction: 1 K refrigerator
- R&D activities for double-cell targets is underway

- ERR: June 21, 2018 ➡ Postponed to winter 18/19
- Refrigerator completion date: Aug, 2018
- Refrigeration tests: Aug. – Dec., 2018
- Single-cell DNP tests: Jan. – May, 2019
- Double-cell DNP tests: July – Dec., 2019
- Full system tests: Jan. – April, 2020
- Ready for installation: May, 2020