

Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, March 31 2017

Publications:

CLAS 2016-08

Exclusive eta electro-production at $W > 2$ GeV with CLAS and Transversity GPDs

I. Bedlinskiy et al., Phys. Rev. C 95 (2017) n.3, 035202.

CLAS 2016-09

Target and beam-target spin asymmetries in exclusive pion electro-production for $Q^2 > 1$ GeV². II $ep \rightarrow e\pi^0 p$

P.E. Bosted et al., Phys. Rev. C 95 (2017) n.3, 035207.

CLAS 2016-07

Target and beam-target spin asymmetries in exclusive pion electro-production for $Q^2 > 1$ GeV². II $ep \rightarrow e\pi^+ n$

P.E. Bosted et al., Phys. Rev. C 95 (2017) n.3, 035206.

CLAS 2016-04

Beam-target double-spin asymmetry in quasi-elastic electron scattering off the deuteron with CLAS

M. Mayer et al., Phys. Rev. C 95 (2017) n.2, 024005.

CLAS 2015-07

Target and Double Spin Asymmetries of Deeply Virtual π^0 Production with a Longitudinally Polarized

Proton Target and CLAS, A. Kim et al., accepted by PLB.

Ad Hoc Review

Analysis	Data	Lead Author	In progress
Measurement of two-photon exchange effect by comparing elastic $e^\pm p$ cross sections	TPE/eg5	Dipak Rimal Brian Raue	Done Feb 16. Submitted to PRC.
Determination of the proton spin structure functions for $0.05 < Q^2 < 5.0 \text{ GeV}^2$ using CLAS	eg1	Robert Fersch	Done Dec 16. Final revisions for PRC.
Beam spin asymmetries of $ep \rightarrow ep\eta$ in the deep inelastic regime	e1f	Andrey Kim	Done Sep 15. Working on paper.
Semi-inclusive π^0 target and beam-target asymmetries from 6 GeV electron scattering with CLAS	eg1-dvcs	Keith Griffioen	Started on Dec 16 1 st round done in Feb 17

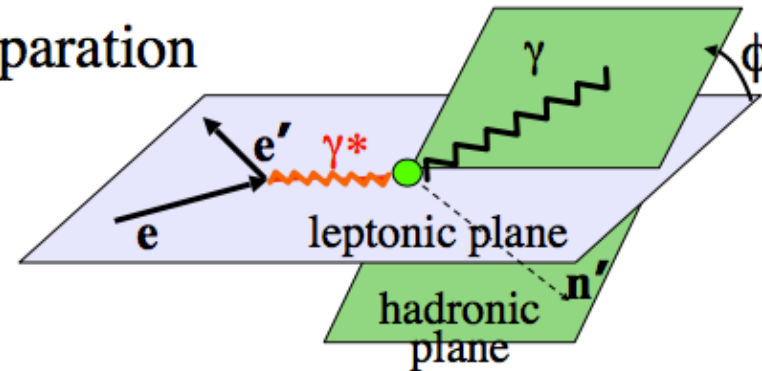
Analysis Review

Analysis	Data	Author	In progress
Hard exclusive backward-angled single charged pion electro-production from the proton at CLAS	e1-dvcs2	Kijun Park	Done Feb 17
DVCS cross section from e1-dvcs2 experiment	e1-dvcs2	Nicholas Saylor	Done Feb 17
Beam asymmetries in exclusive π^+ electro production for $W > 1.7$ GeV from e16	e16	Peter Bosted	Ongoing
Exploring the structure of the proton via semi-inclusive pion electro-production	e1f	Nathan Harrison Kyoungseon Joo	Ongoing
Measurement of the spin structure g_1^d of the deuteron and its moments at low Q^2	eg4	Krishna Adikhari	Started this week

Analysis Review

Analysis	Data	Author	In progress
Exclusive electroproduction of the $f_0(980)$ and $f_2(1270)$ on the proton with CLAS	e1f	Brice Garillon Silvia Niccolai	Brice busy with other project, V2 in one month
Di-hadron beam spin asymmetry in SIDIS electro production	eg1-dvcs	Silvia Pisano	Silvia busy with other project Last version in one month
Deep-virtual production of the ρ^+ meson off the proton	e1-dvcs	Ahmed Fradi	Ahmed busy with other projects. Slow progress
Semi-inclusive pion production	e16	Mikhail Osipenko	Working on a better alignment
Time-like Compton scattering	g12	Ibrahim Abayrak	Last record 2015

- GPDs from proton and neutron: flavour separation
- Neutron DVCS extremely sensitive to E , least-known and least-constrained GPD



$\vec{e^-}$ n Polarized beam, unpolarized neutron target:

$$\Delta\sigma_{LU} \sim \sin\phi \operatorname{Im}\{F_1 \mathbf{H} + \xi(F_1 + \tilde{F}_2) \mathbf{H} - kF_2 \mathbf{E}\} d\phi \longrightarrow \mathbf{H}_n, \tilde{\mathbf{H}}_n, \mathbf{E}_n$$

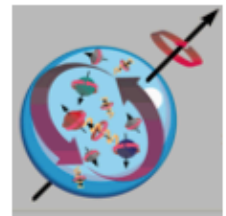
Suppressed because $F_1(t)$ is small

Suppressed because of cancellation between PDF's of u and d quarks

Ji's relation: $J^q = \frac{1}{2} - J^g = \frac{1}{2} \int_{-1}^1 x dx \{H^q(x, \xi, 0) + E^q(x, \xi, 0)\}$

$$J_N = \frac{1}{2} = \frac{1}{2} \Sigma_q + L_q + J_g$$

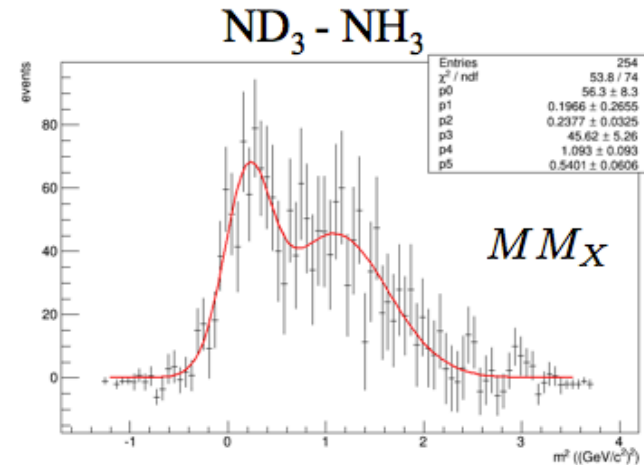
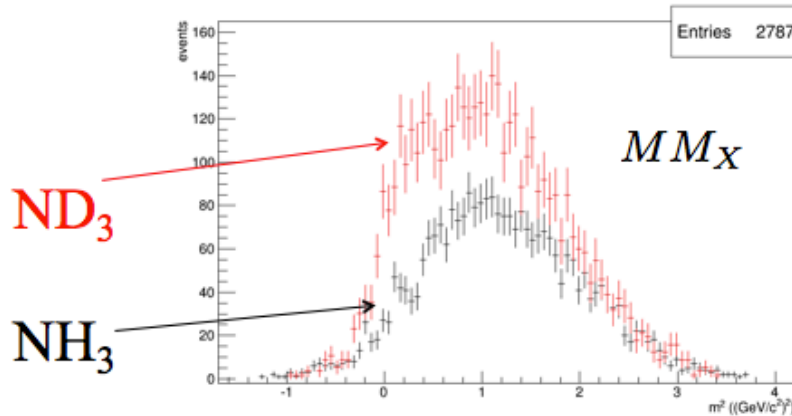
Important missing link in the nucleon spin puzzle!



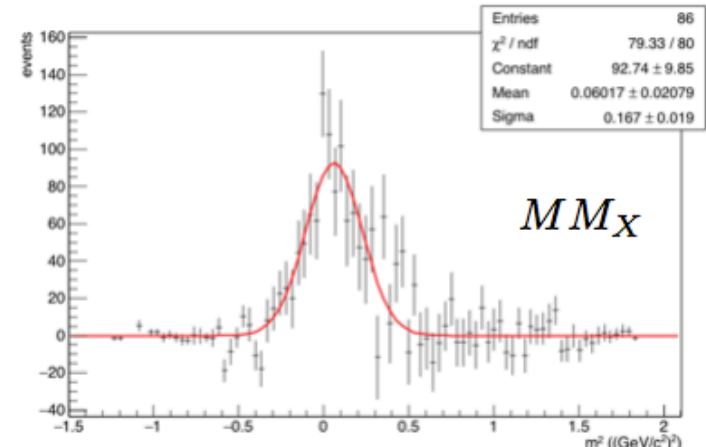
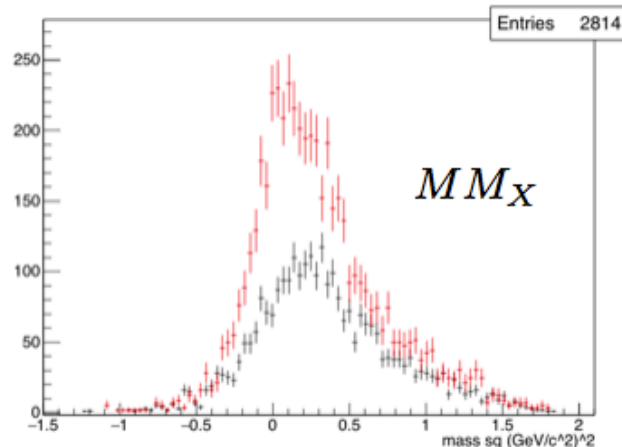
After exclusivity cuts

Missing mass from $eN \rightarrow e' N X$ (should correspond to **photon**)

- Neutron momentum calculated from beta:



- Neutron momentum calculated from kinematics:



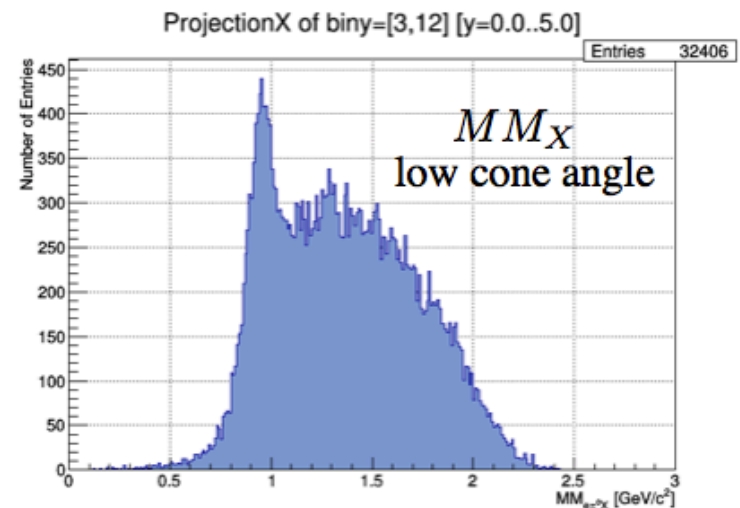
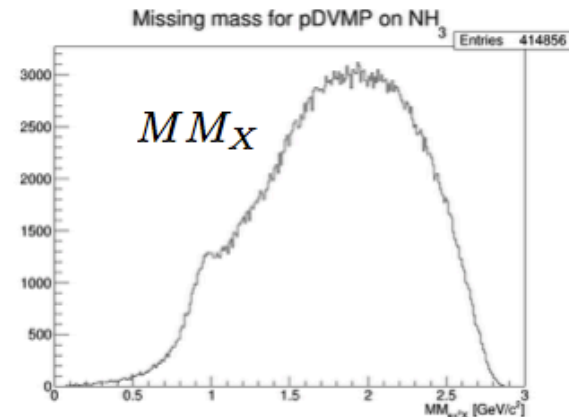
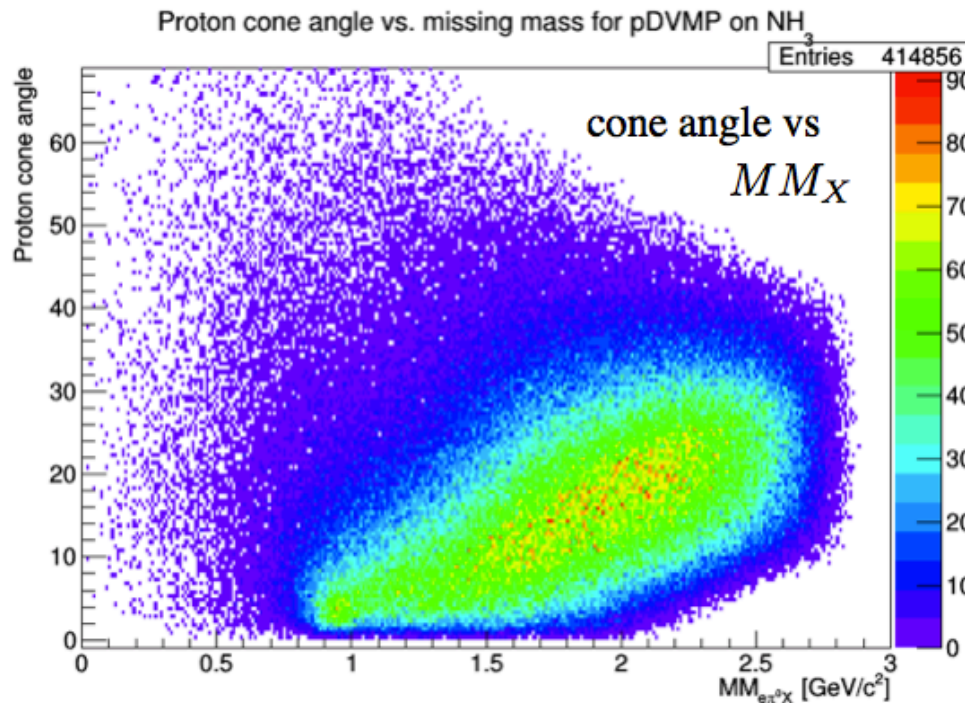
Recoil reconstruction: p-pi0 on NH3

Try reconstructing neutrons from missing mass and neutron candidate direction, determine cut on basis of p-pi0. Start with pi0 electro-production on proton (part B data):

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

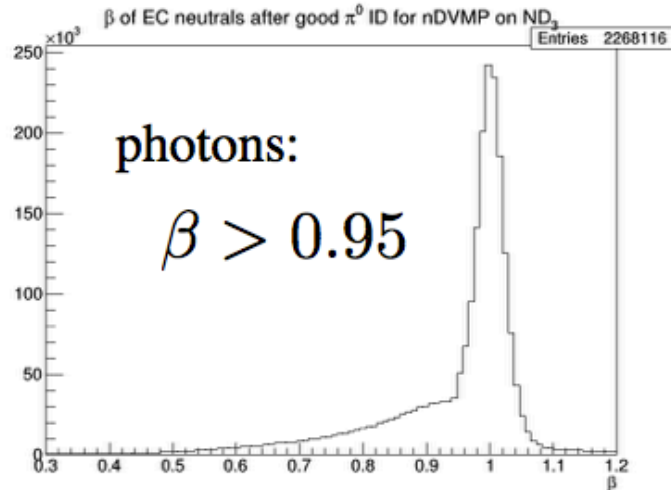
Gavin Murdoch, Glasgow University

Cone angle: between calculated and measured nucleon direction.

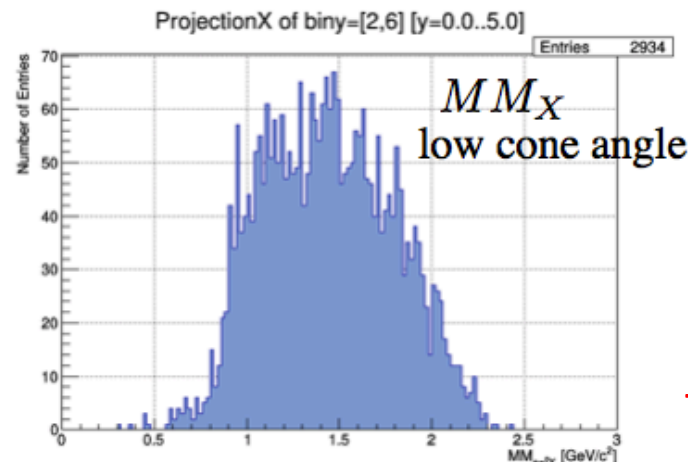
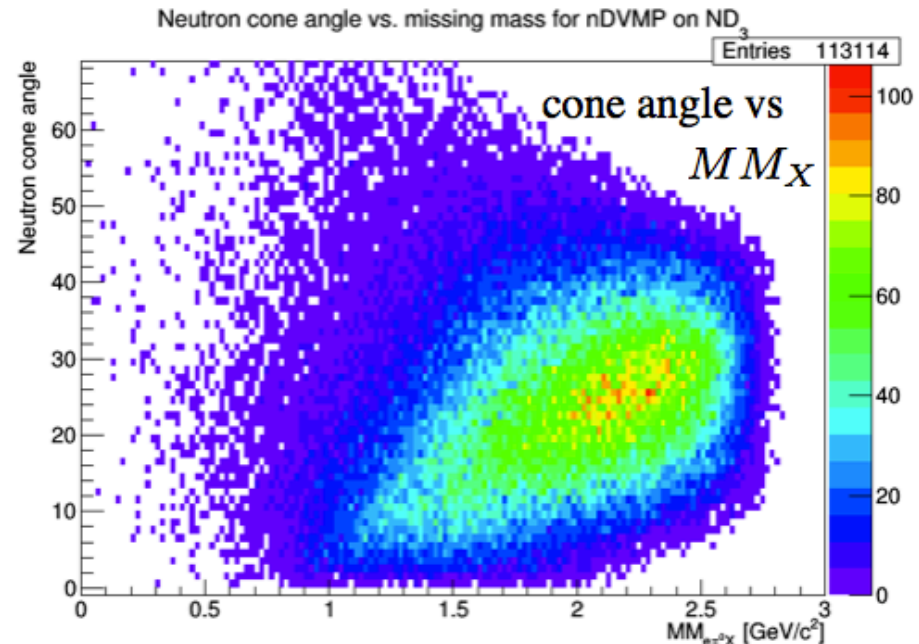
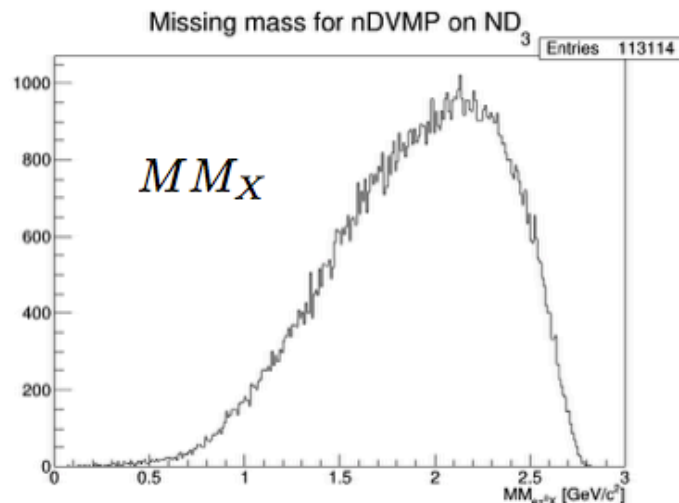


Recoil reconstruction: n- π^0 on ND3

Gavin Murdoch, Glasgow University



$$e + n \rightarrow e' + \pi^0 + X$$

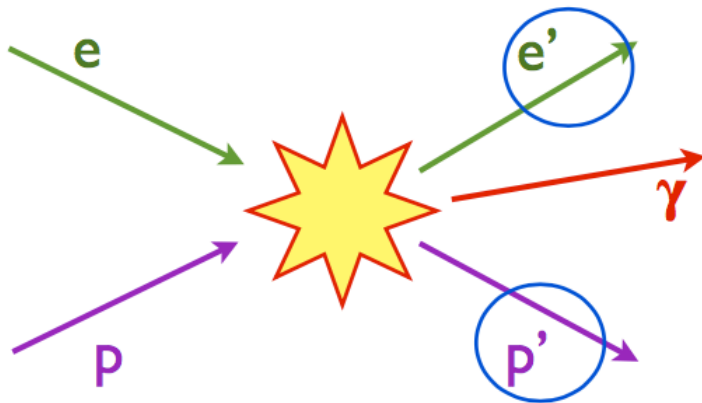


Neutron
efficiency low, no
discernible peak.

Try to explore π^+ channel

STATUS OF DVCS ANALYSIS FROM E1-6 DATA

Aram Movsisyan



Measurement of DVCS Cross Section,
via detection of final state proton p' and
lepton e' .

Large statistics & broad kinematic
coverage \Rightarrow large coverage of Φ
acceptance.

E1-6 experiment:

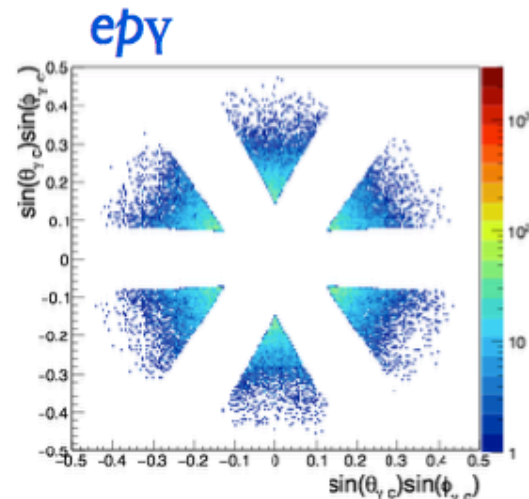
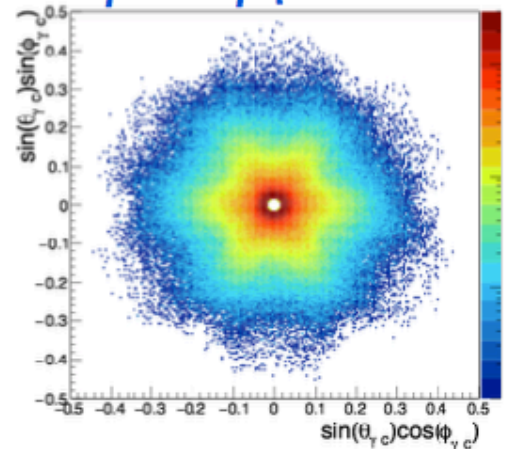
Data collected in 2001-2002.

Beam energy 5.754 GeV

5cm long liquid hydrogen target

Average beam polarization 70%

spatial distributions of calculated photons
ep & ep γ

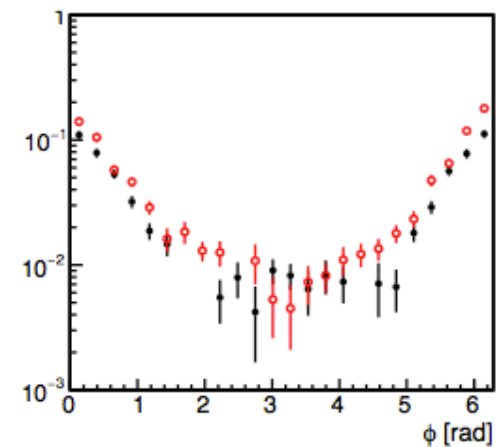
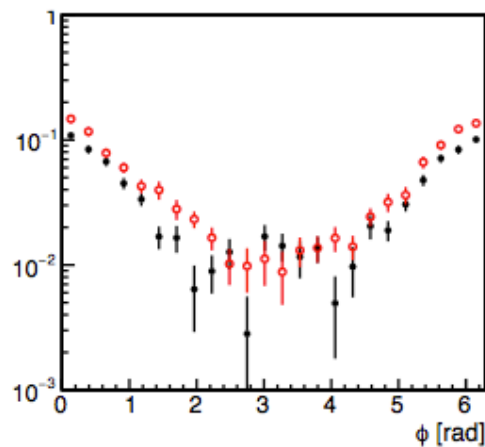
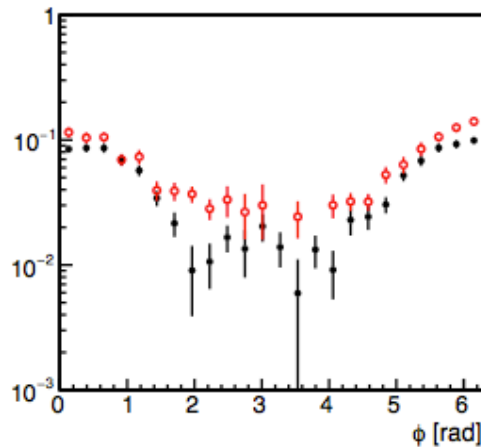
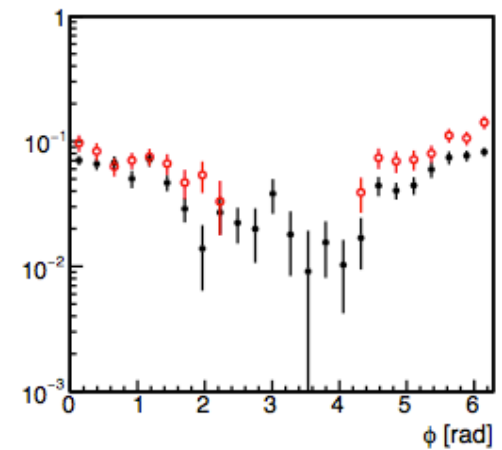
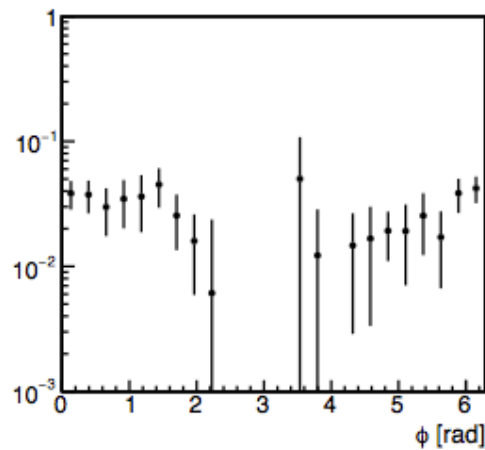
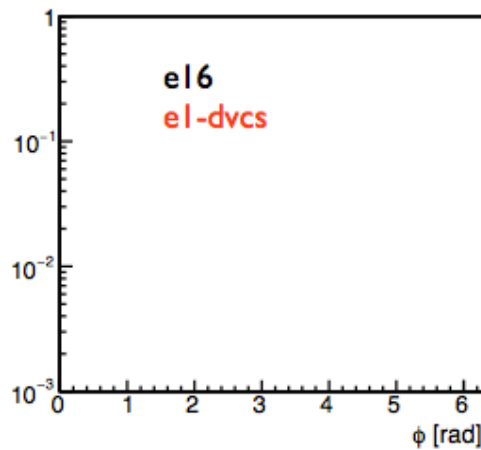


Comparison with Published Results

Bin17

$x_{Bj} = [0.35 - 0.38]$

$\theta = [28 - 45]$



Exclusive photons ($ep\gamma$ sample)

Data - MC comparison **exclusive photons**:

$$W^2 > 4 \text{ [GeV}^2\text{]}$$

$$0.07 < -t < 0.52 \text{ [GeV}^2\text{]}$$

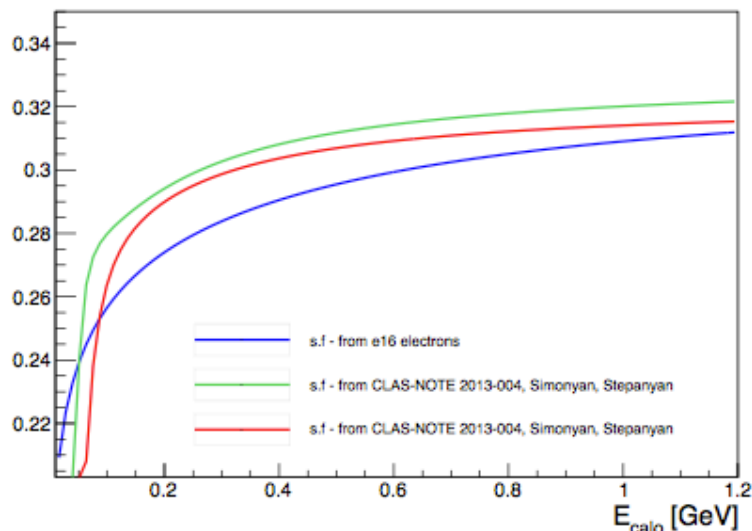
$$|M_X^2(epX)| < 0.08 \text{ [GeV}^2\text{]}$$

$$P_{ele.} > 0.7 \text{ [GeV]}$$

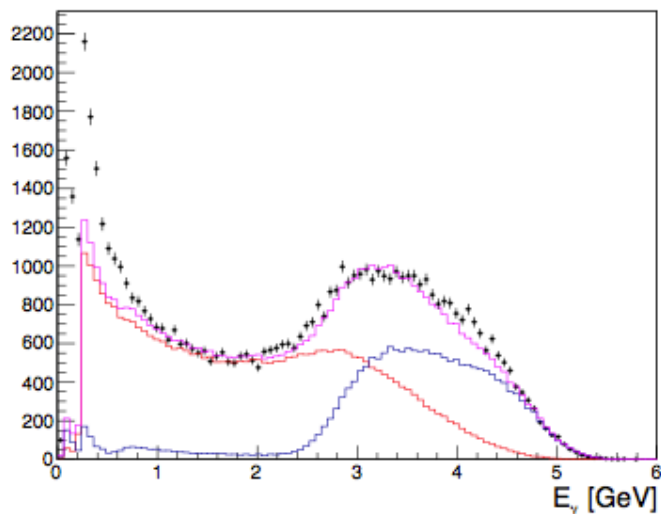
$$t < t_{min}$$

$$\theta_{\gamma calc.} > 2^\circ$$

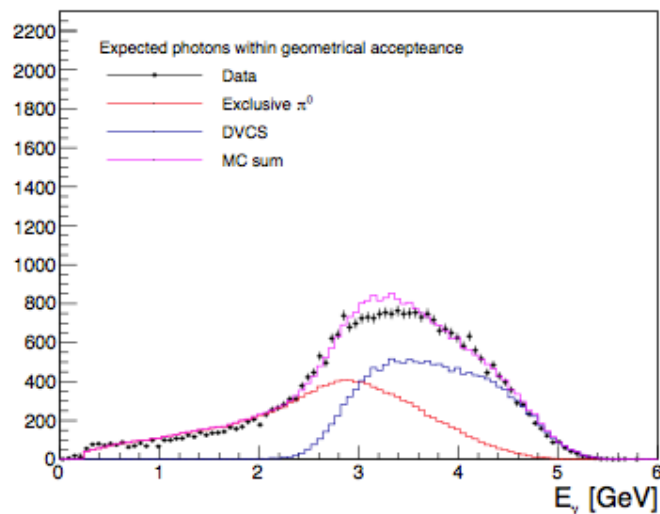
Sampling fraction



Data - MC

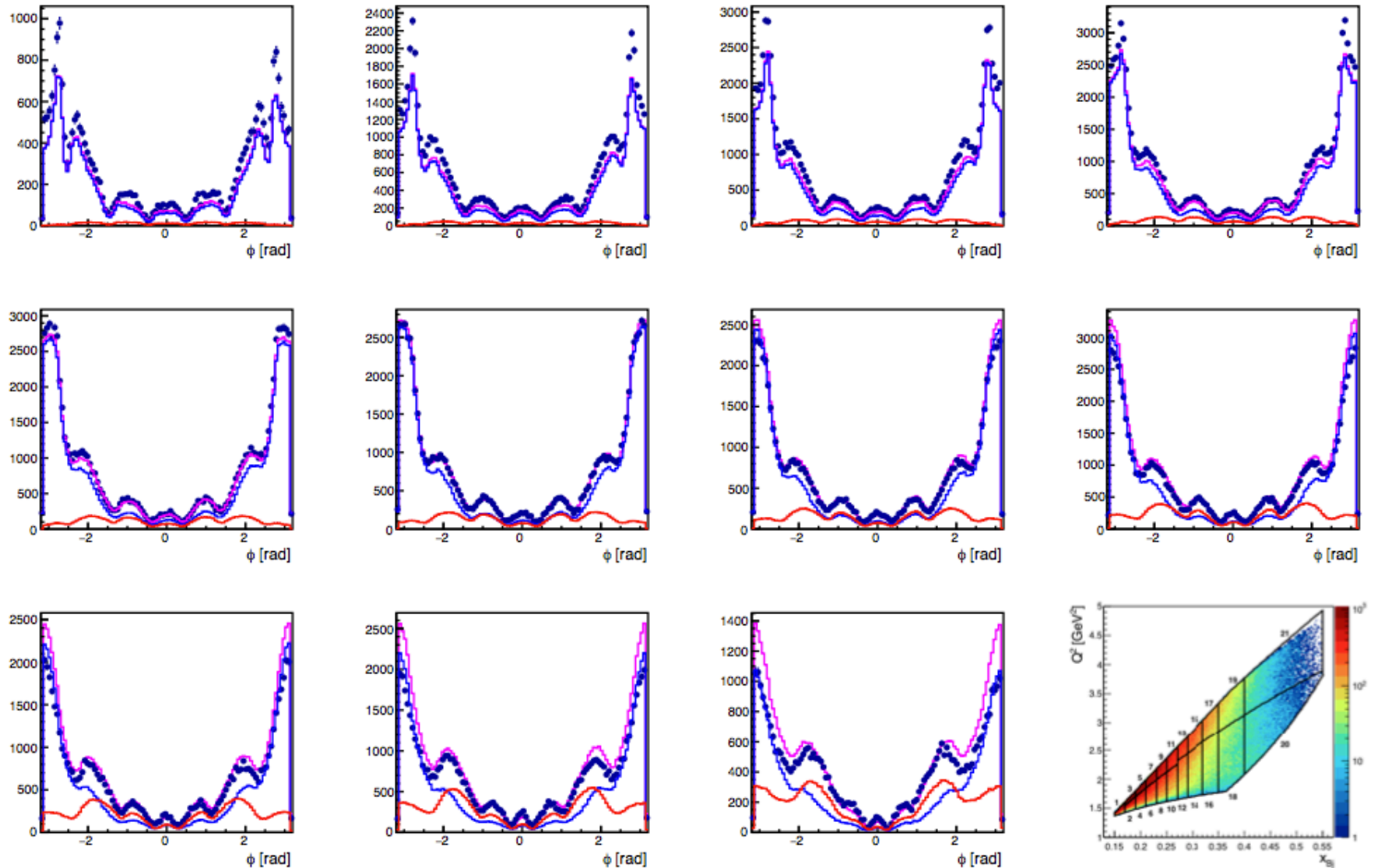


Data - MC

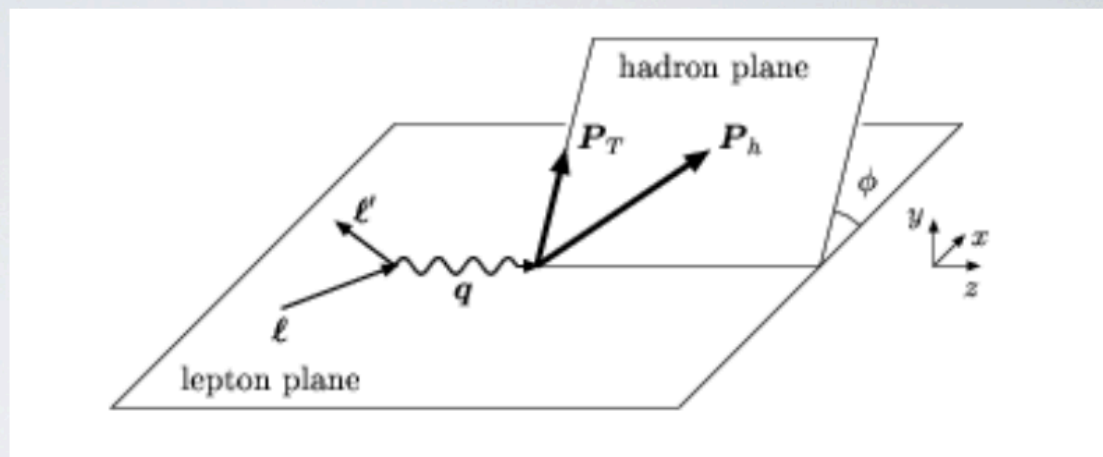


DVCS ($ep + ep\gamma$ sample)

Data - MC comparison (exclusive π^0 , DVCS, MC sum):



unpolarized
beam/target

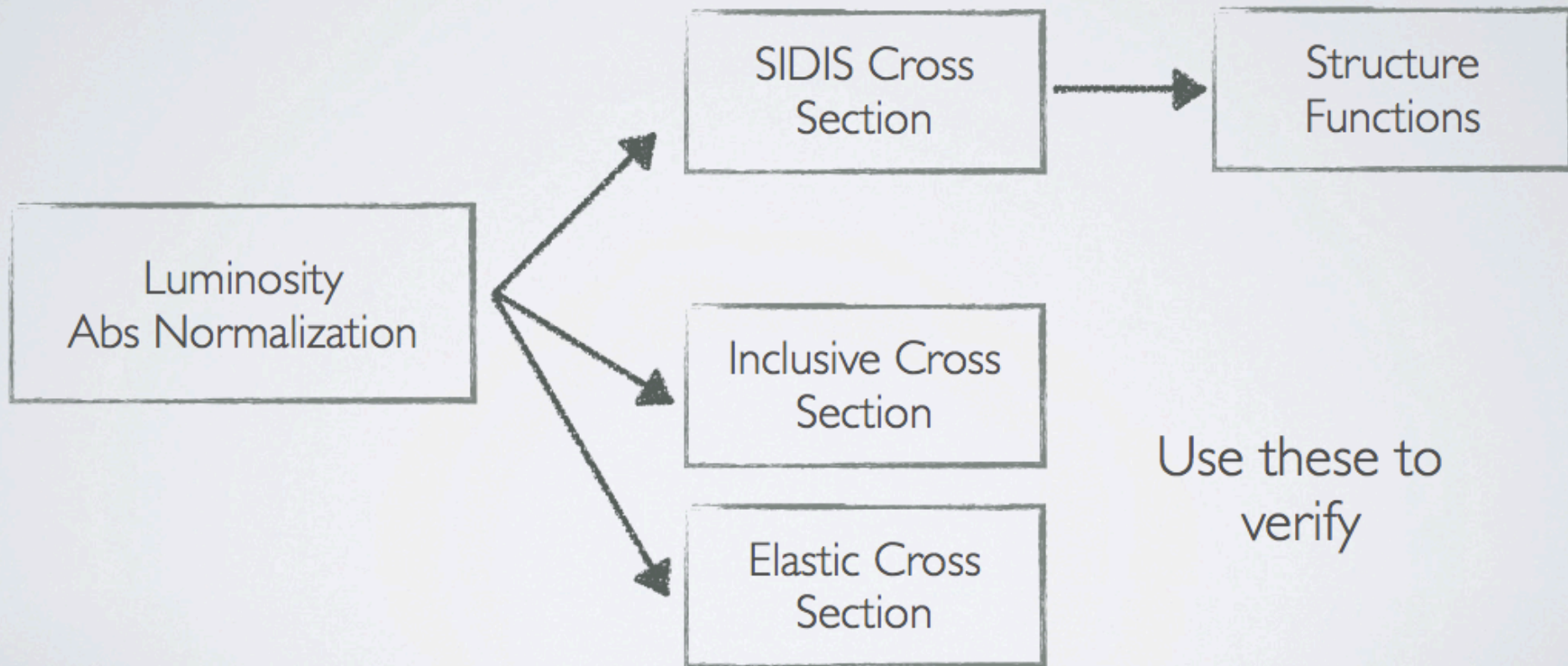


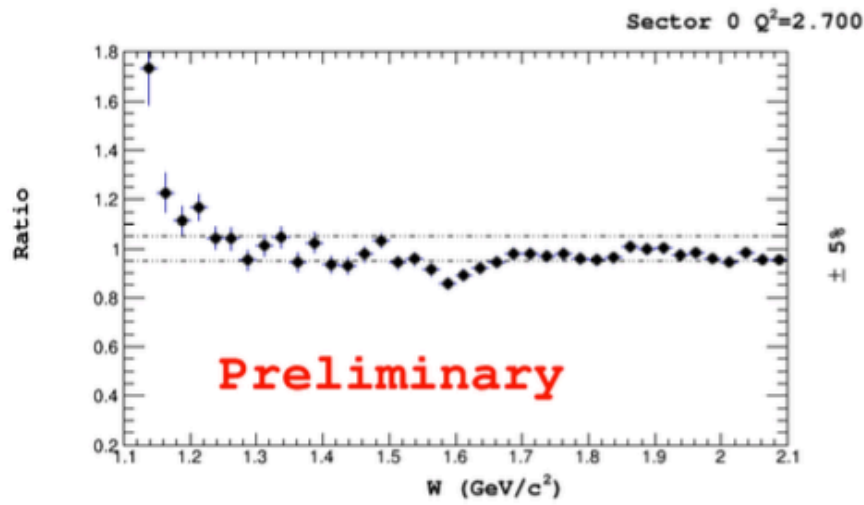
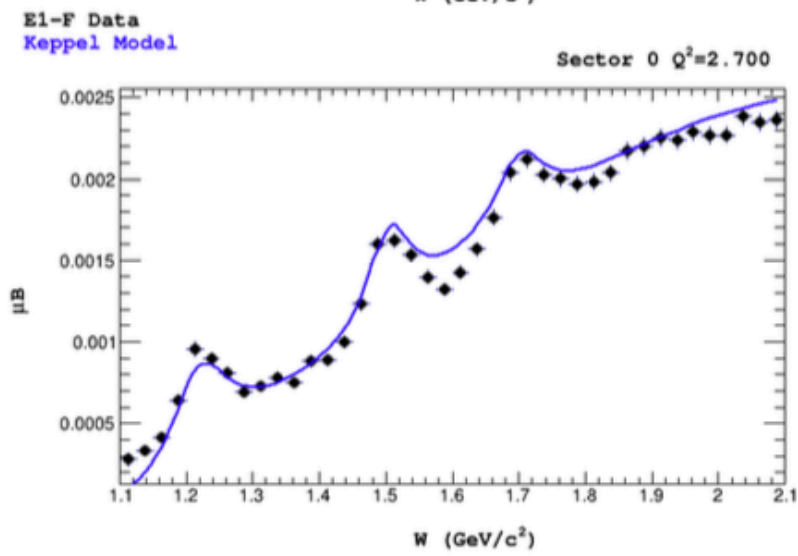
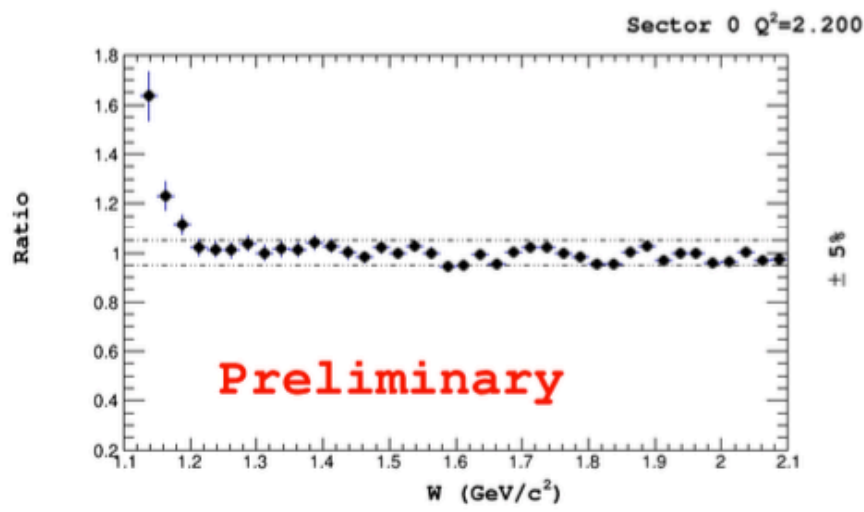
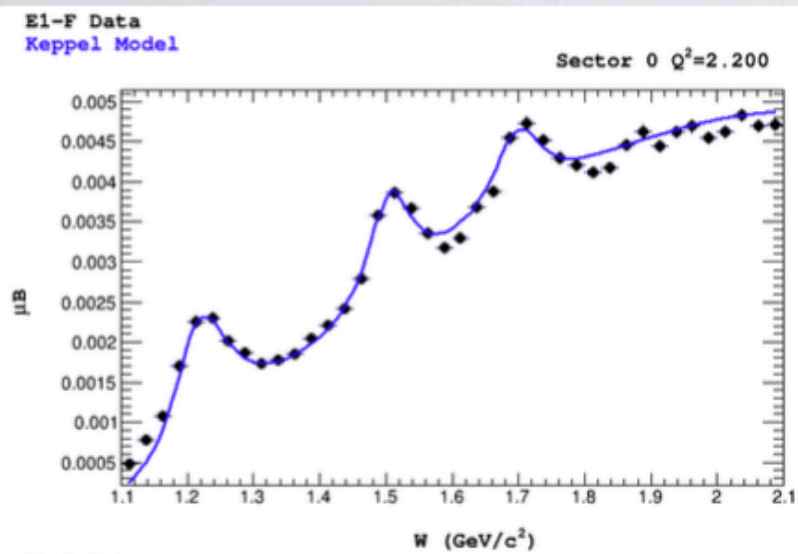
$$\frac{d\sigma^{e^- P \rightarrow e^- h X}}{dx_B dQ^2 dz d\phi_h dp_{h\perp}^2} = \frac{\alpha_{em}^2}{2x_B y Q^2} \frac{y^2}{1-\varepsilon} \left(1 + \frac{\gamma^2}{2x_B}\right) \left\{ \underline{F_{UU,T}} + \varepsilon \underline{F_{UU,L}} \right. \\ \left. + \sqrt{2\varepsilon(1+\varepsilon)} \cos \phi_h \underline{F_{UU}^{\cos \phi_h}} + \varepsilon \cos(2\phi_h) \underline{F_{UU}^{\cos 2\phi_h}} \right\}$$

Model Independent Formulation in
terms of Structure Functions

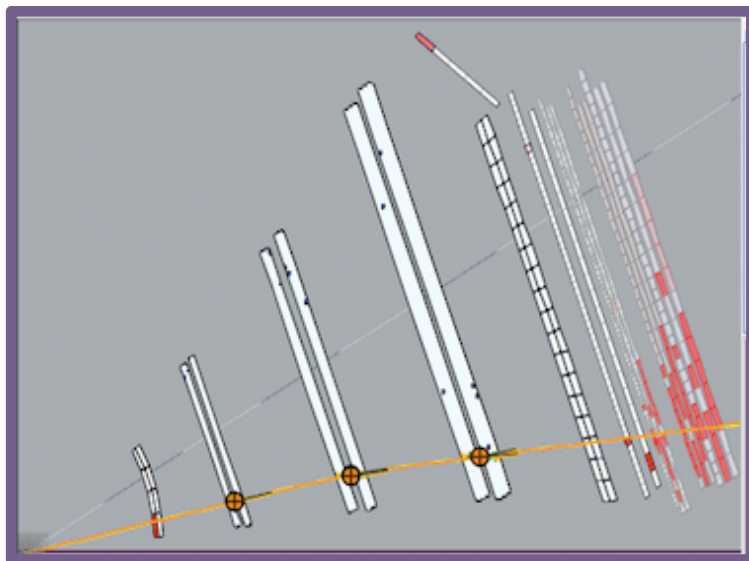
To take the next step we need **luminosity**

$$A_{UU} \rightarrow F_{UU}$$

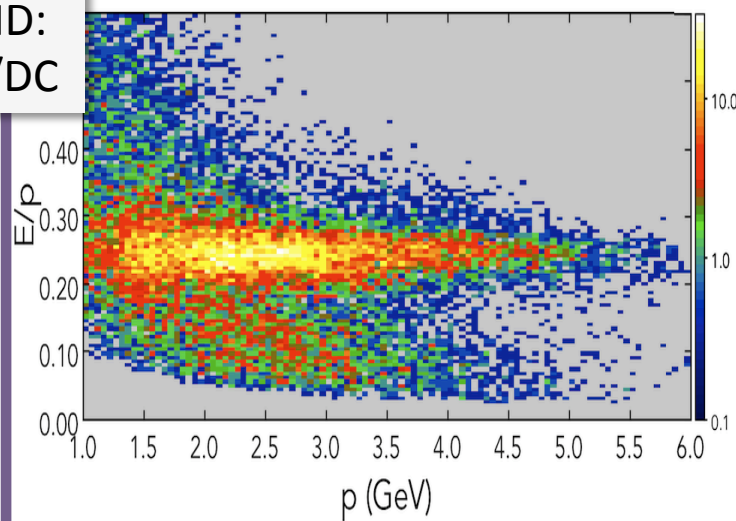




KPP run: a crucial milestone

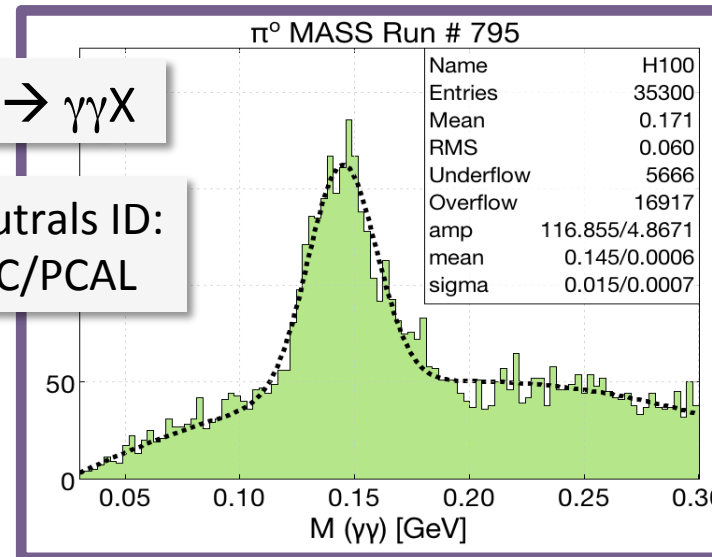


Electron ID:
EC/PCAL/DC

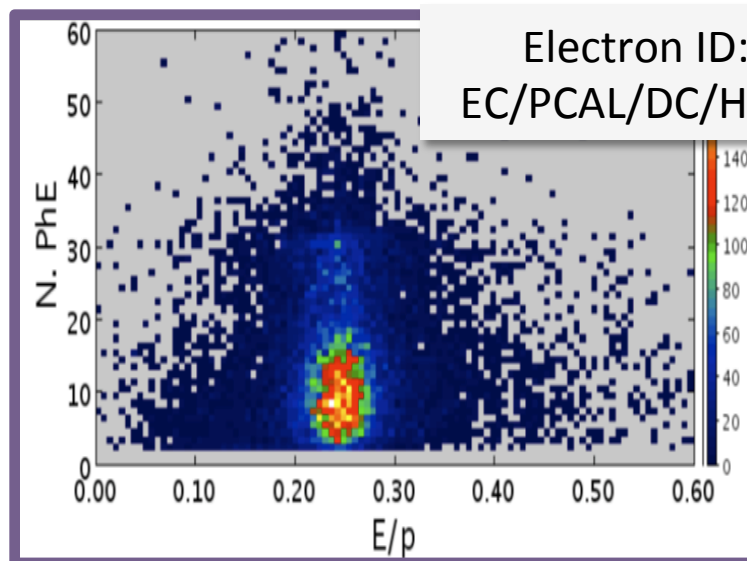


$e\ ^{12}\text{C} \rightarrow \gamma\gamma X$

Neutrals ID:
EC/PCAL



Electron ID:
EC/PCAL/DC/HTCC



Everybody in DPWG is in charge to make the first CLAS12 experiments a success

Thursday, 30 March 2017


08:00 - 13:00 **Deep Processes: Remote connection:** <https://bleajeans.com/191186756> ▼

Convener: Marco Contalbrigo (INFN Ferrara)

Location: CEBAF Center (A110)

08:45 **Deep Processes Working Group Business 15'** ▼

Speaker: Marco Contalbrigo (INFN Ferrara)

Material: **Slides** 

09:00 **Report from ACE 20'** ▼

Speaker: Sebastian Kuhn (ODU)

Material: **Slides**  


09:20 **Report from Run Group A 20'** ▼

Speaker: Jacques Ball (CEA-Saclay)

Material: **Slides**  

09:40 **Report from Run Group B 20'** ▼

Speaker: Silvia Niccolai (IPN Orsay)

Material: **Slides** 

Run groups have grown during time collecting HI, high rated or even unrated PAC experiments

Issues among required configurations should be addressed within the group or with Hall-B management

Available manpower should be revisited

Silvia Niccolai took over the run-group B leadership as Kawtar Hafidi has now other obligations at ANL

ACE: Analysis Committee of Experts



To-Do List (The Agenda)

1. Common Tools to do the following (DST generation)

- o Good run, file and event selection
- o Compile list of special runs required (calibration, in/outbending, no B, H, 2.2 GeV...)
- o Helicity sorting and matching, false asymmetries
- o Beam and target polarization, dilution, polarized background
- o Luminosity
- o PID
- o Backgrounds
- o Vertex and momentum corrections
- o Fiducial cuts and acceptance
- o Detector and reconstruction inefficiencies
- o Kinematic fitting
- o Radiative corrections
- o Simulation of all of the above (GEMC)

Increase efficiency

Ensure high-quality standards

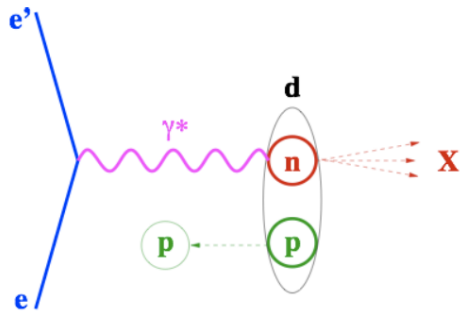
Do not prevent custom developments

2. “Model” analysis notes, algorithms, checklists...

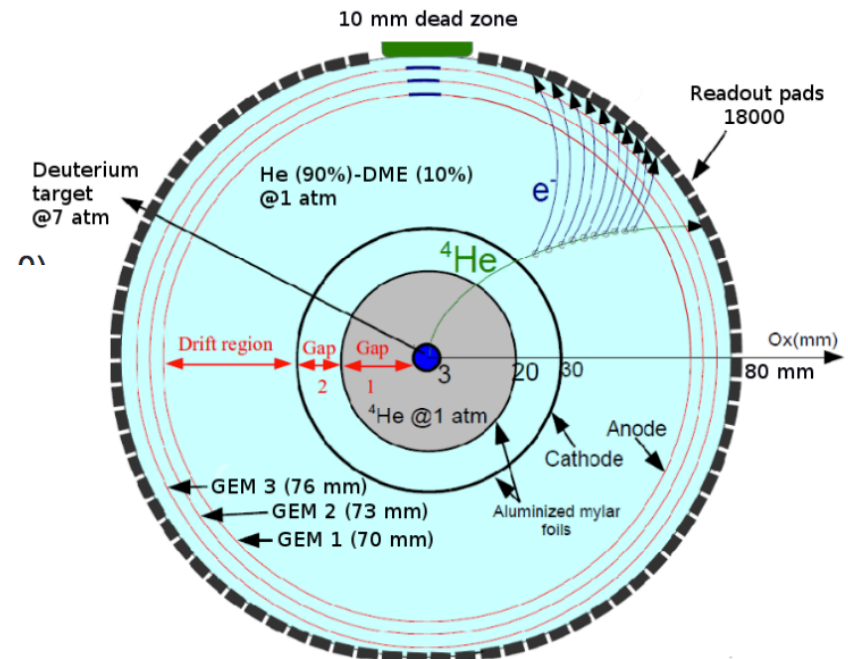
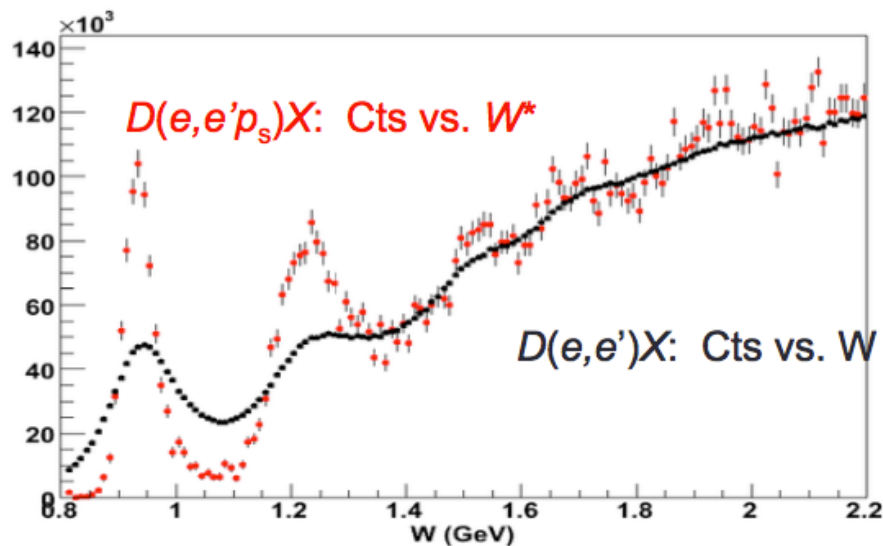
BONuS Experiment

Carlos Ayerbe G.

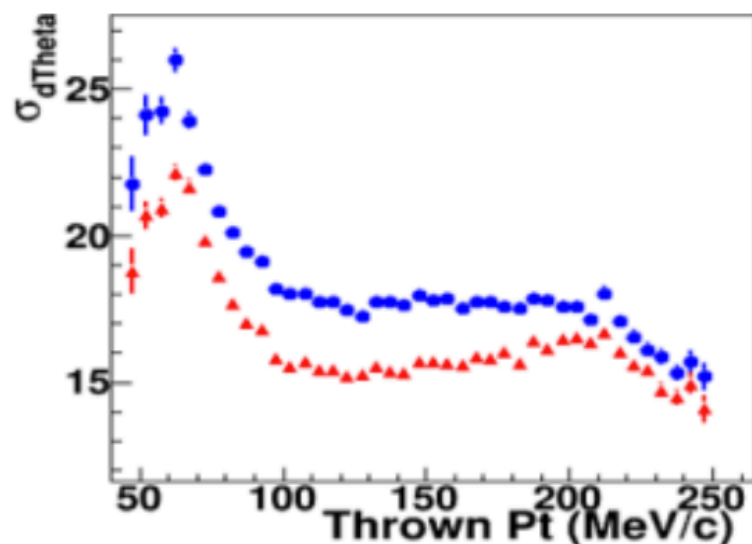
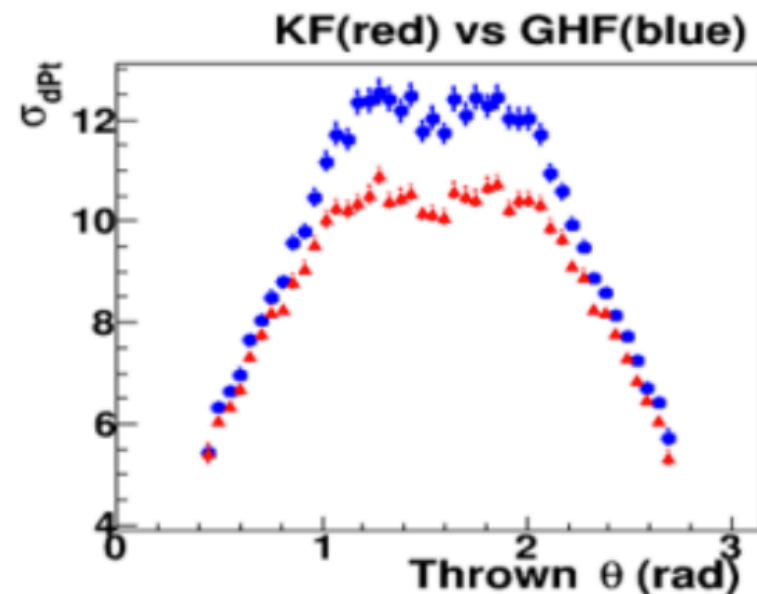
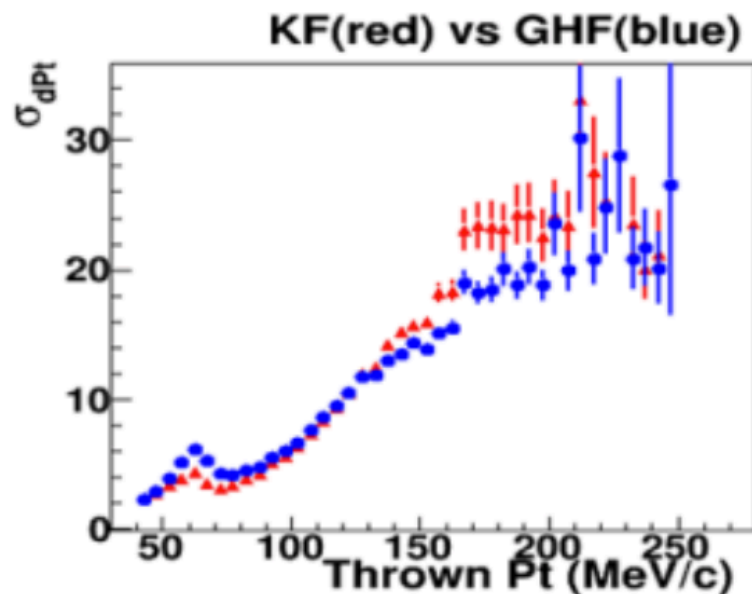
- Barely Off-Shell Nucleon Structure experiment E12-06-113



Measurement of neutron SF
with spectator tagging technique



Kalman filter performance

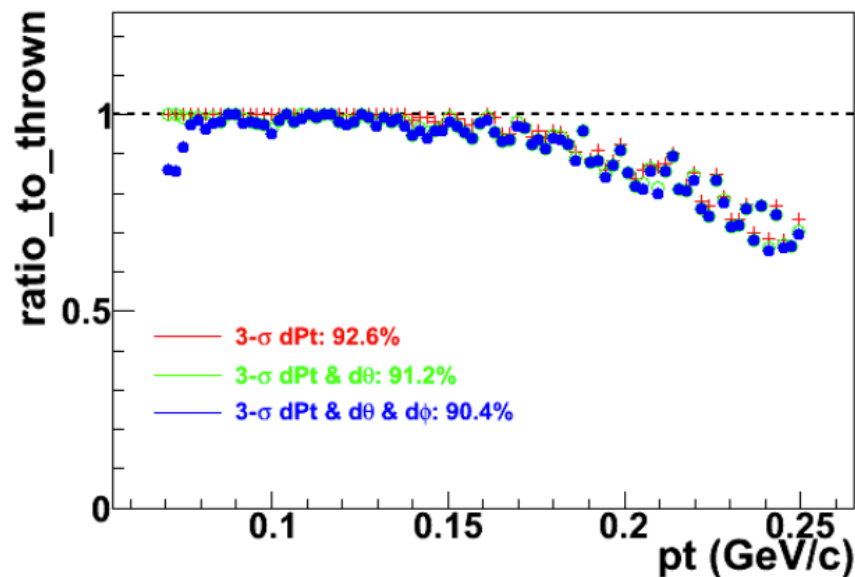
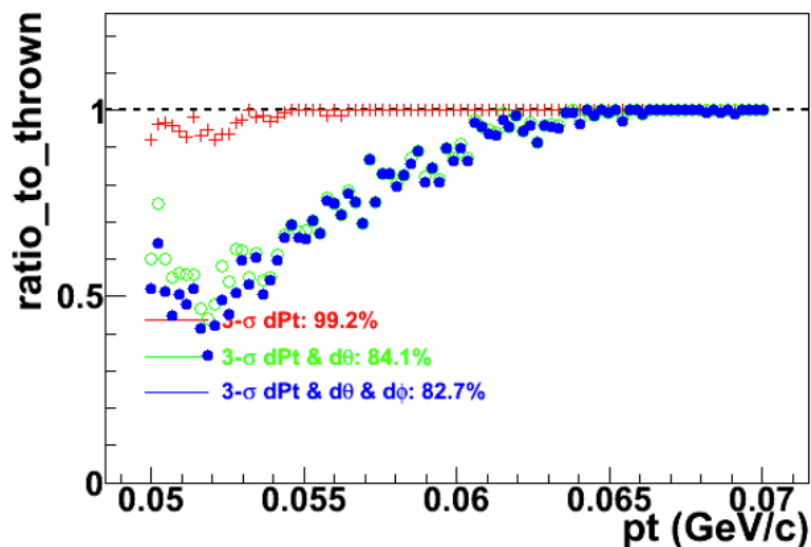


In simulated data, KF shows equal or better performance than Global Helix Fitter used previously

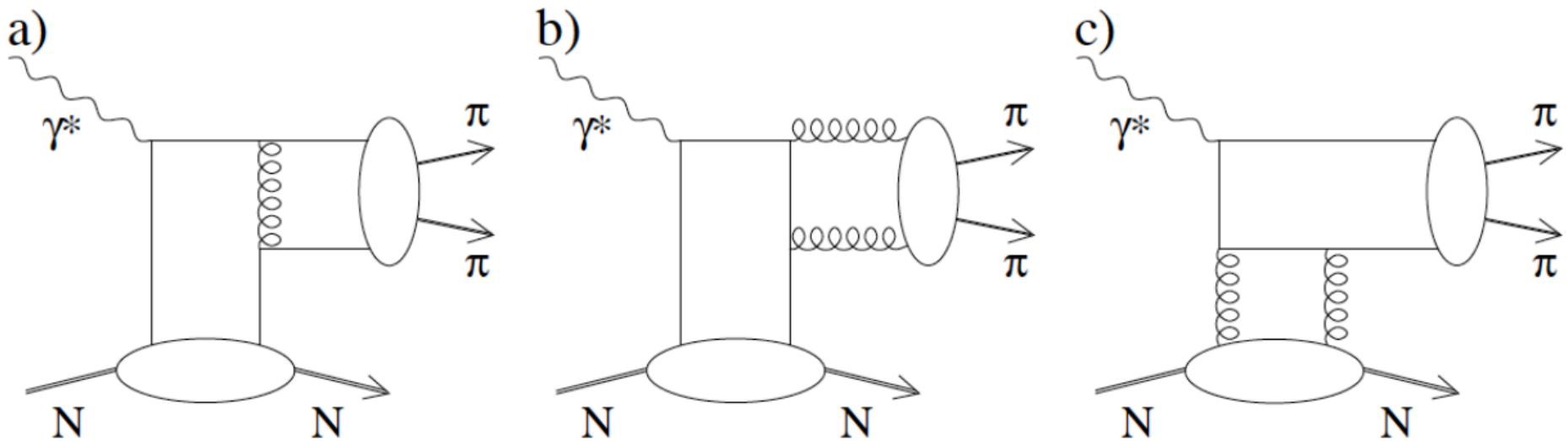
Present status

- RTPC12 Tracking Software v0.97 has been released and it is being tested by the BONuS Simulation and Analysis group.
- The code is available in github:

<https://github.com/jixie/KaIRTPC>



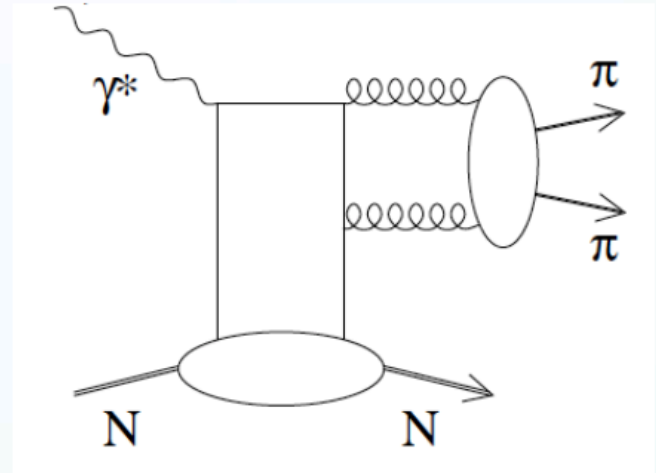
Deep Virtual Production of $\pi\pi$ Pairs



- B. Lehmann-Dronke *et al.*, Phys Lett B **475** (2000) 147
- B. Lehmann-Dronke *et al.*, Phys Rev D, **63** (2001) 114001
- Neutral mesonic final state: $\pi^+\pi^-$ or $\pi^0\pi^0$
 - a) [Flavor-Diagonal quark-GPD] \otimes [$q\bar{q}$ -Two-Pion Distribution Amplitude (DA)]
 - b) [Flavor-Diagonal quark-GPD] \otimes [gluon-Two-Pion Distribution Amplitude (DA)]
 - c) [Gluon-GPD] \otimes [$q\bar{q}$ -Two-Pion Distribution Amplitude (DA)]

Deep sigma

- σ -meson: $f_0(500)$ well established
 - **Pole** = $(450 \pm 20) \text{ MeV} - i(275 \pm 12) \text{ MeV}$
- 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
- σ -meson Asymptotic Distribution Amplitudes:
 $\Phi_{\text{gluon}} = 2 \Phi_{qq}$
- Deep sigma-production offers intriguing evidence for gluonic content of $f_0(500)$
- We have started to write a MC generator based on the Lehmann-Dronke formalism.



Conclusions

CLAS6: DPWG pretty active

Latests:

- 5 publications
- 4 ad hoc review (3 just concluded)
- 10 analysis review (2 just concluded)
- several analysis ongoing

CLAS12: DPWG is committed to make the 12 GeV era a success

Working on hardware and software

Exploring new physics channels

Looking forward to contribute and conform to ACE recommendations