Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, June 16th 2017

Publications:

CLAS 2015-07
Target and Double Spin Asymmetries of Deeply Virtual pi0 Production with a Longitudinally Polarized Proton Target and CLAS, A. Kim et al., Phys. Lett. B. 768 (2017) 168.

CLAS 2016-02
Measurement of two-photon exchange effect by comparing elastic $e^{\pm}p$ cross sections,
D. Rimal, Phys. Rev. C 95, (2017) 065201.

Ad Hoc Review

Analysis	Data	Lead Author	In progress
Determination of the proton spin structure functions for $0.05 < Q^2 < 5.0$ GeV^2 using CLAS	**eg1**	**R. Fersch**	Done Author check.
Semi-inclusive π^0 target and beam-target asymmetries from 6 GeV electron scattering with CLAS	**eg1-dvcs**	**S. Jawalker** **K. Griffioen**	Done Near author check
Beam spin asymmetries of ep->epη in the deep inelastic regime	**e1f**	**A. Kim**	3rd round in Sep 15
Hard exclusive backward-angled single charged pion electronproduction from the proton at CLAS	**e16**	**K. Park**	1st round in May
DVCS cross section from e1-dvcs2 experiment	**e1-dvcs2**	**N. Saylor**	1st round in May

Analysis Review

Analysis	Data	Author	In progress
Beam asymmetries in exclusive π^+ electro production for W> 1.7 GeV from e16	**e16**	**P. Bosted**	Ongoing
Exploring the srtructure of the proton via semi-inclusive pion electroproduction	**e1f**	**N. Harrison** **K. Joo**	Ongoing
Measurement of the spin structure g_1^d of the deuteron and its moments at low Q^2	**eg4**	**K. Adihari**	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, V2 in one month
Di-hadron beam spin asymmetry in SIDIS electro production	**eg1-dvcs**	**S. Pisano**	Silvia busy with other project Last version in one month
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, 15th June 2017

Finalize 6 GeV data analyses

- Interesting results still in the pipeline

Anticipate the analysis stages and needs of run groups close to take data

- RGB, RGA

Promote synergies between 6 GeV analyses and 12 GeV developments:

- 6 GeV data providing a benchmark
  exploitation of the CLAS12 new tools and procedures to the 6 GeV data;

Initiate 12 GeV simulations of detectors or physics channels with CLAS12 tools

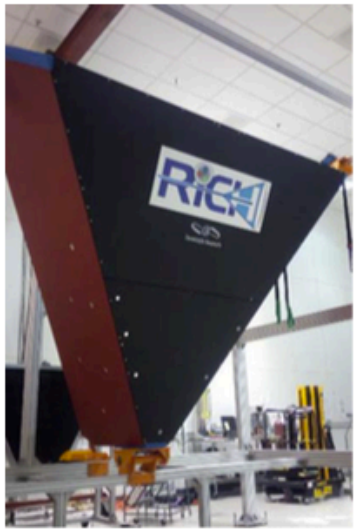
- few examples relevant for SIDIS and exclusive channels

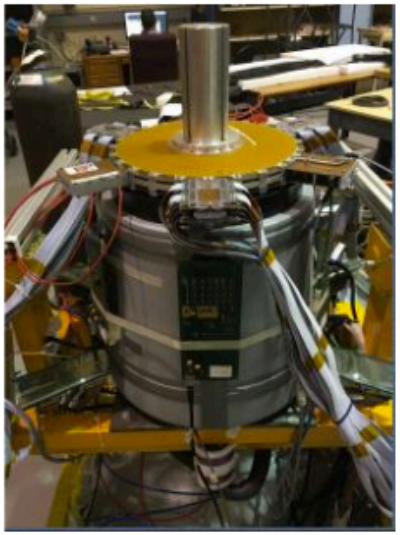
Run-Group B: running conditions

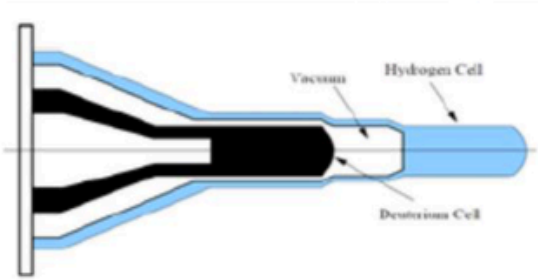
Neutron magnetic form factor	Dual target	A- 30
Study of partonic distributions in SIDIS kaon production	*Dual target*, RICH	A- 56
Boer-Mulders asymmetry in K SIDIS	*Dual target*, RICH, two field settings	A- 56
Deeply virtual Compton scattering on the neutron	Single-cell target, CND, FT	A (HI) 90 ★
Collinear nucleon structure at twist-3	*Dual target*, RICH	--
In medium structure functions, SRC, and the EMC effect	Single-cell target, BAND	--

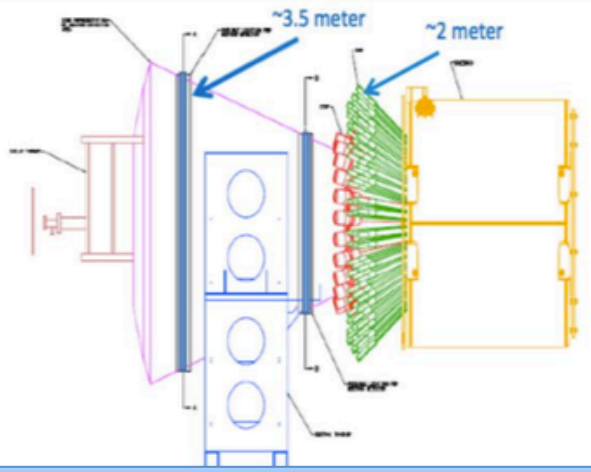
Readyness for 2018 run:

- Single-cell target, CND, RICH and FT will be already in RG A
- BAND and dual target status? New equipment requires ERR







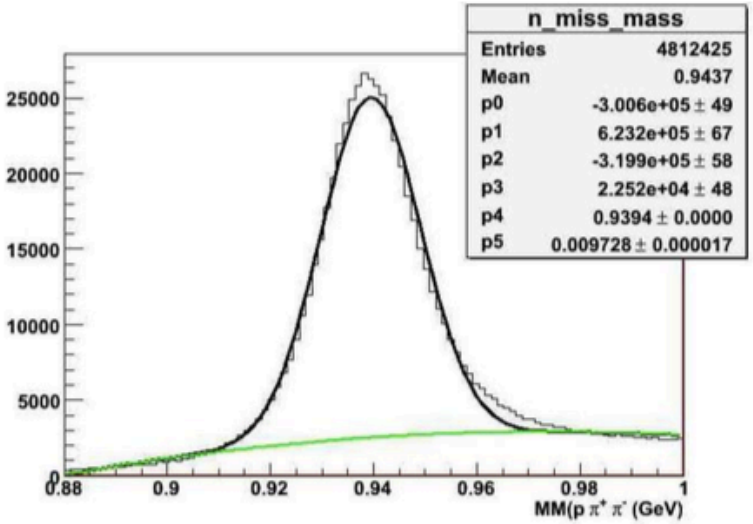


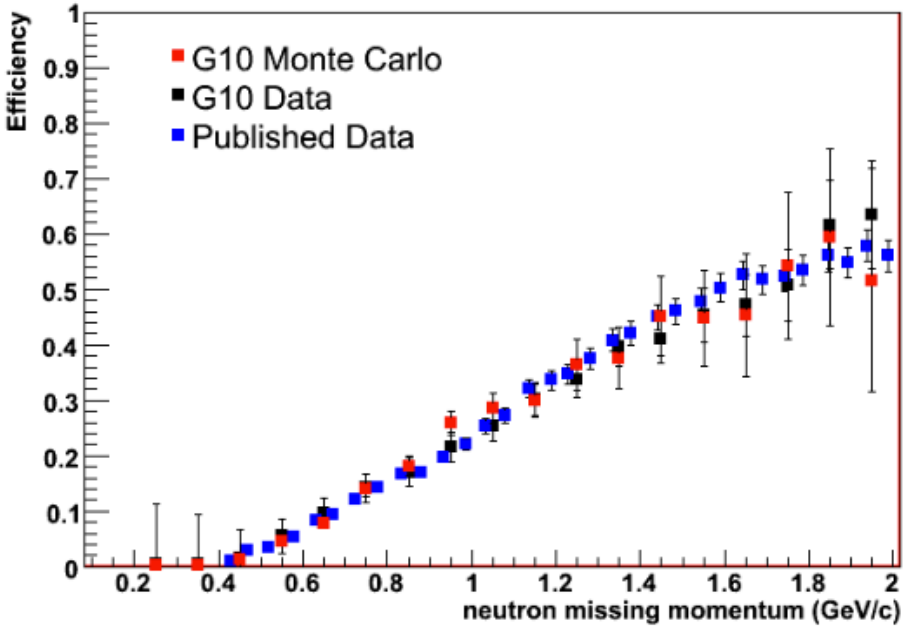
Alternative idea: using deuterium data for NDE

Work by S. A. Pereira on g10 data set.

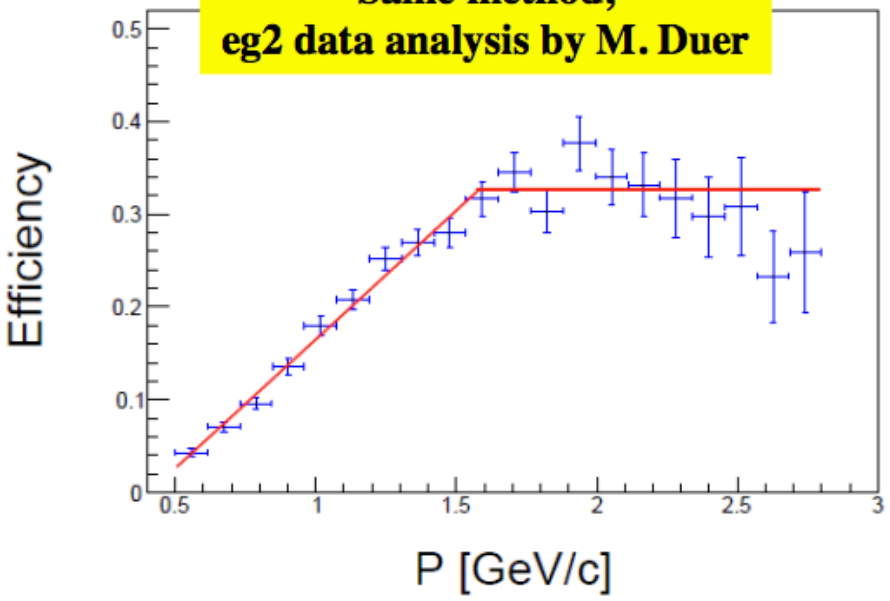
Chosen reaction $\gamma d \rightarrow p n \pi^+ \pi^-$. Exclusivity cuts:

- Missing mass of $\gamma d \rightarrow p\pi^+\pi^- X$
- Angle between the direction of expected and measured neutron
- Polar angle Θ_{miss} between 10° and 45°
- Azimuthal angle Φ_{miss} in the sector reference frame
- Background subtraction under missing mass peak





Same method, eg2 data analysis by M. Duer



Pion&Kaon SIDIS with CLAS12

Harut Avakian

DeepPWG meeting , JLab, June 15, 2017

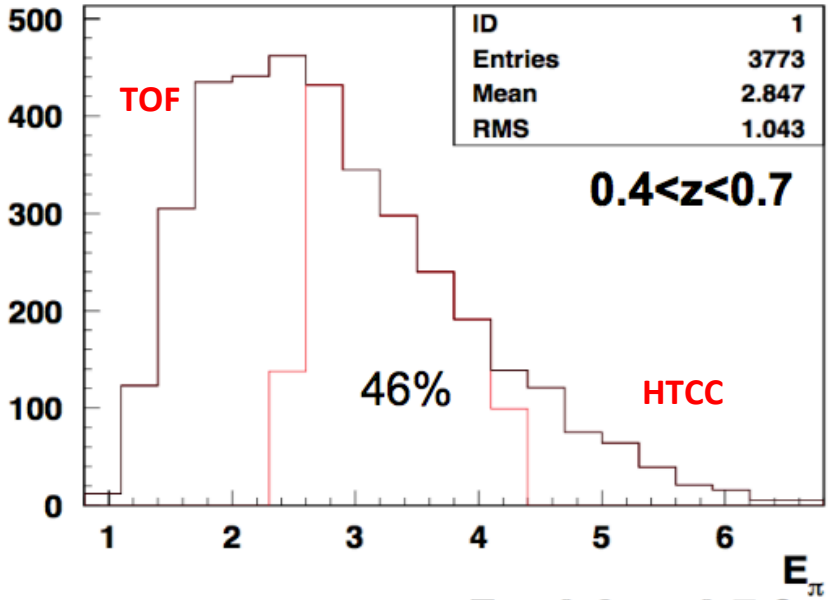
Hall B – Run Groups

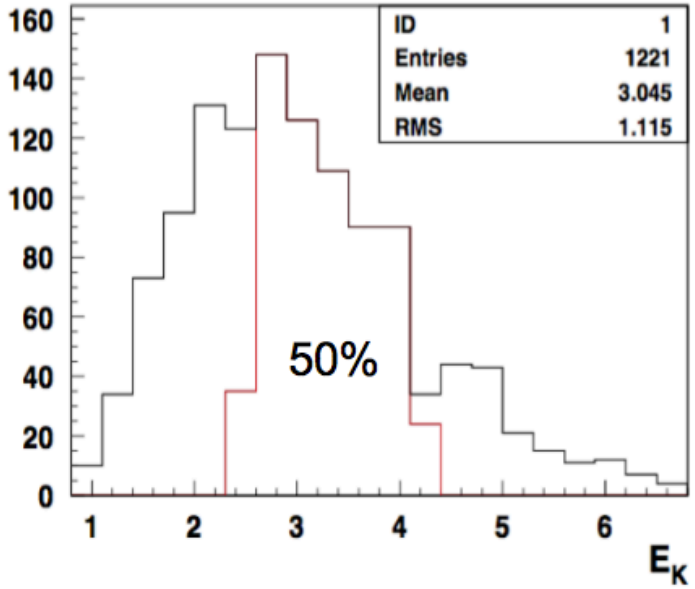
Hall B

Proposal	Physics	Contact	Rating	Days	Group	New equipment	Energy	Run Group	Target
E12-06-108	Hard exclusive electro-production of π^0, η	Stoler	B	80		RICH (1 sector) Forward tagger			liquid H_2
E12-06-108A	Exclusive N*->KY Studies with CLAS12	Carman		(60)					
E12-06-108B	Transition Form Factor of the η' Meson with CLAS12	Kunkel		(80)					
E12-06-112	Proton's quark dynamics in SIDIS pion production	Avakian	A	60				A	
E12-06-112A	Semi-inclusive Λ productiuon in target fragmentation region	Mirazita		(60)	139		11	F. Sabatié	
E12-06-112B	Colinear nucleon structure at twist-3	Pisano		(60)					
E12-06-119(a)	Deeply Virtual Compton Scattering	Sabatie	A	80					
E12-09-003	Excitation of nucleon resonances at high Q^2	Gothe	B+	40					
E12-11-005	Hadron spectroscopy with forward tagger	Battaglieri	A-	119					
E12-11-005A	Photoproduction of the very strangest baryon	Guo		(120)					
E12-12-001	Timelike Compton Scatt. & J/ψ production in e+e-	Nadel-Turonski	A-	120					
E12-12-007	Exclusive φ meson electroproduction with CLAS12	Stoler, Weiss	B+	60					

Pion distributions and contamination

ERR: Develop a plan to ensure there is sufficient C4F10 available for operation in Fall 2017, or demonstrate how the planned physics goals may be achieved with out it.





For 0.3<z<0.7 fraction decreases to 40%

40-50 % of pions and kaons are in the range of 2.5<P<4.2 GeV not covered by other detectors

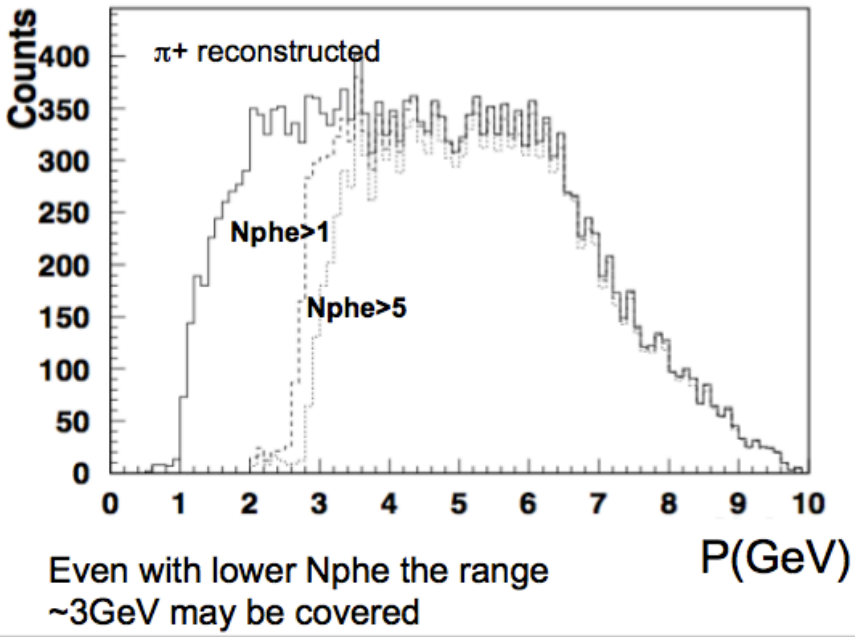
The fraction of K+/π+~0.25 and K-/π- ~0.15 in the range of 2.5<P<4.2 GeV

Need detailed studies of Kaons to understand the effect of ~10% contamination

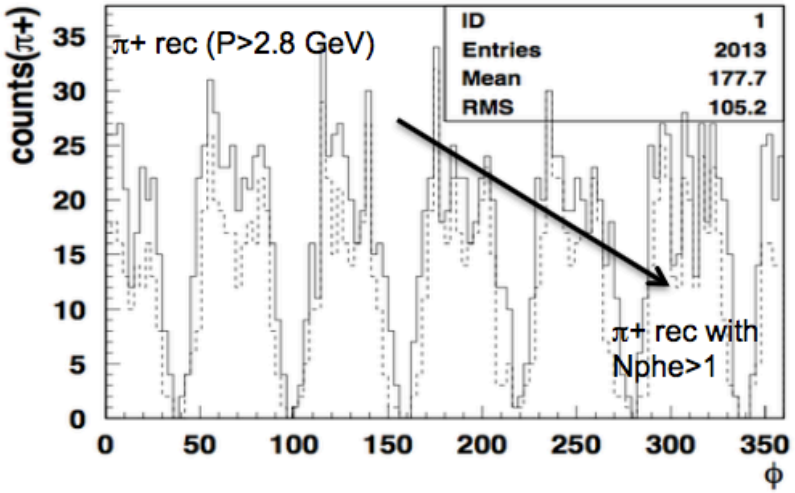
CLAS12: LTCC response

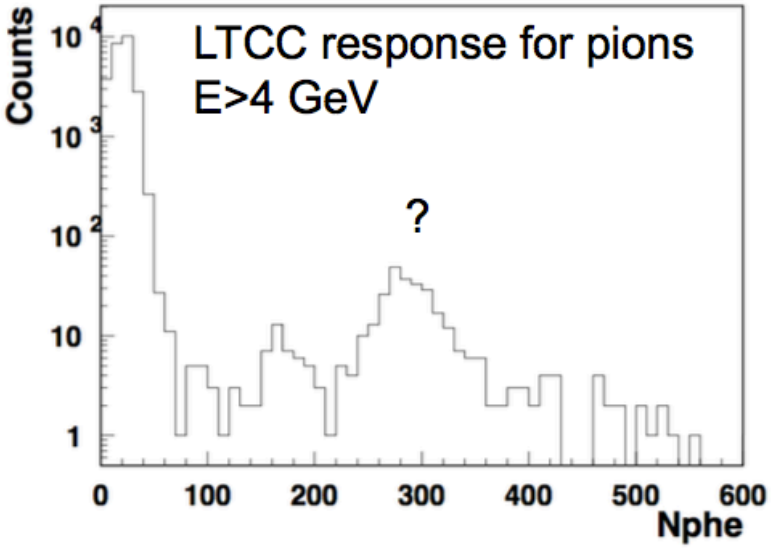
Generators:
Single uncorrelated particles (e-,γ, π+)
SIDIS events ep→e'hX

- GEMC 4a.1.0
- COATJAVA 4a.6.0

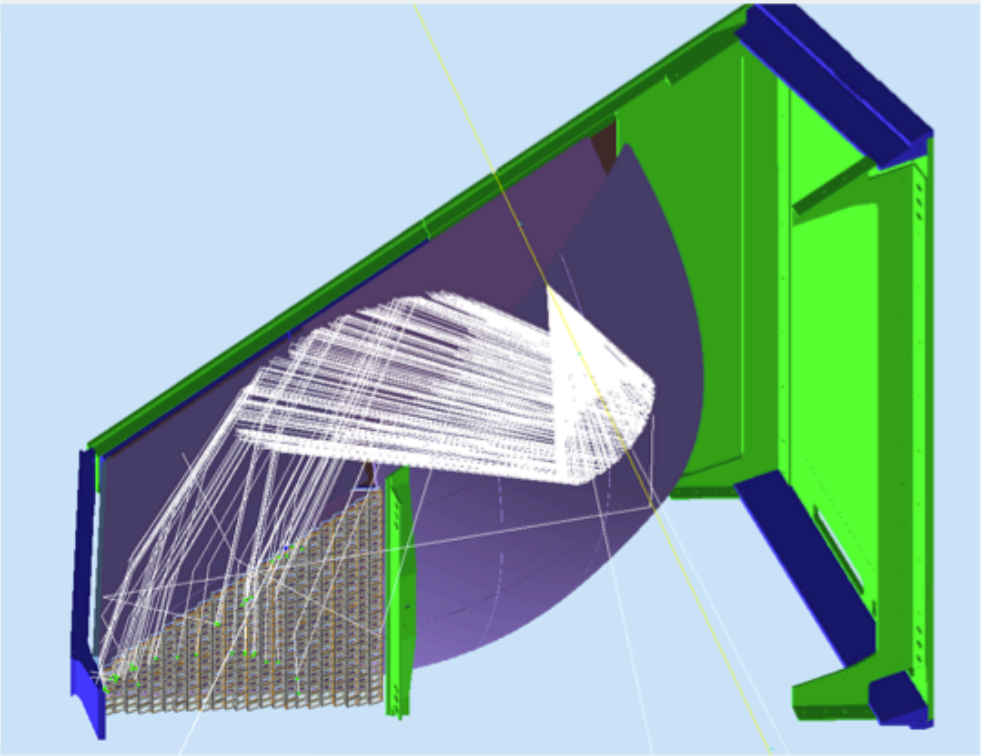


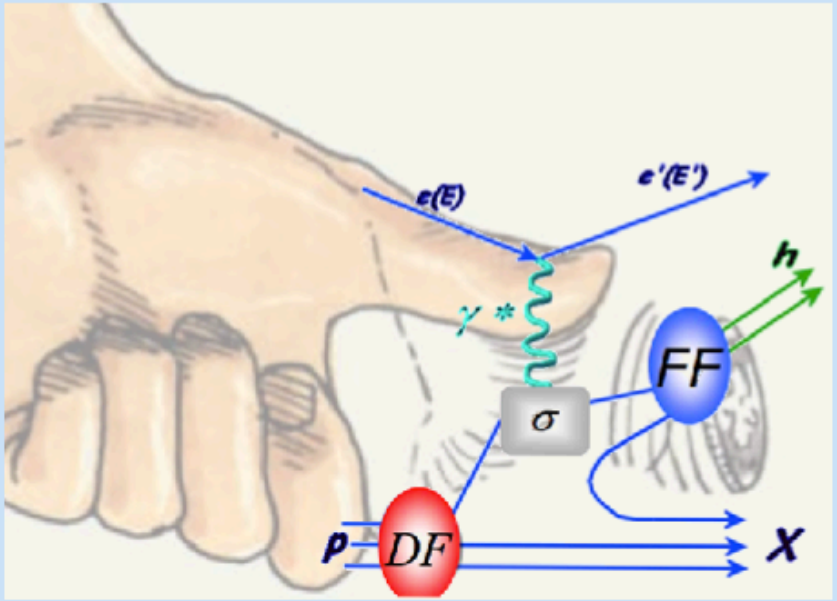
Even with lower Nphe the range ~3GeV may be covered





SIDIS with unpolarized Hydrogen target and Meson yields at CLAS12



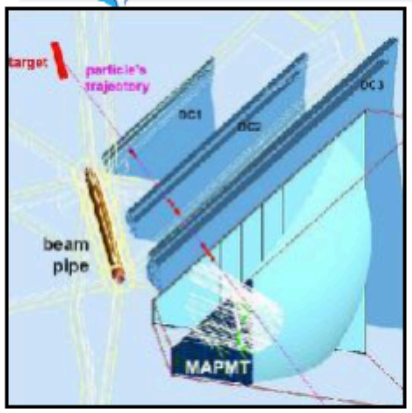


Giovanni Angelini

The George Washington University

gangel@gwu.edu

RICH software status



The RICH collaboration developed simulations and reconstruction algorithms.

We are working to better describe the detector and integrate/improve algorithms into CLAS12 Common-Tools.

Last summer I initiated the use of CAD files for better geometry description (implemented thanks to M. Ungaro).

Successful for several detectors

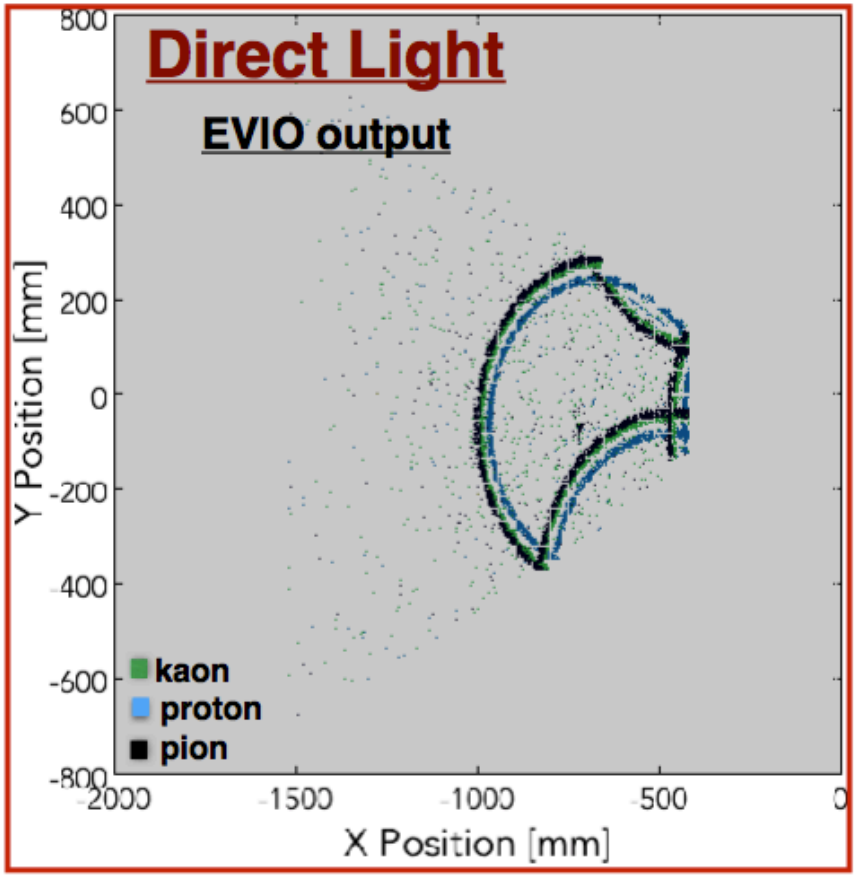
However, today we have still problems with GEMC. Optical photons and CAD volumes hierarchy not working: we cannot integrate our software until we have everything available.

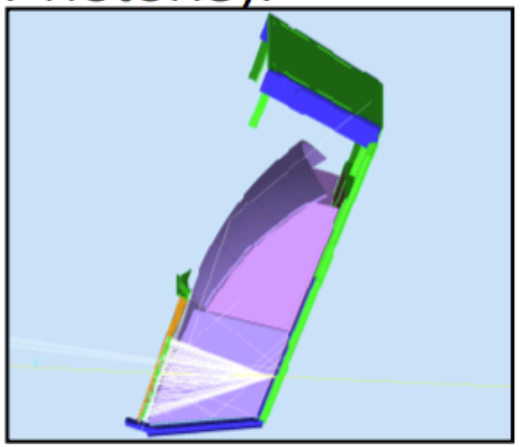
Maurizio Ungaro is working on that issue.
We started the software development outside CLAS12, in a stand alone way!

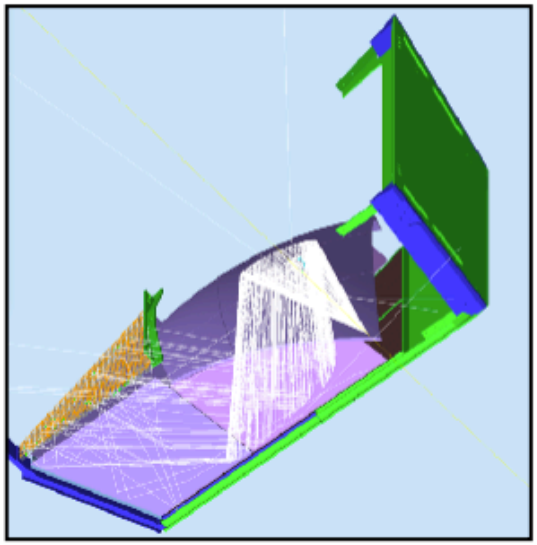
Giovanni Angelini - The George Washington University - gangel@gwu.edu

RICH software status

Now we have a better description of the detector that will give us better performances (but we need Optical Photons).







RICH stand-alone CAD-Geometry

Extraction of Charged Kaon Asymmetries from E1-F Data

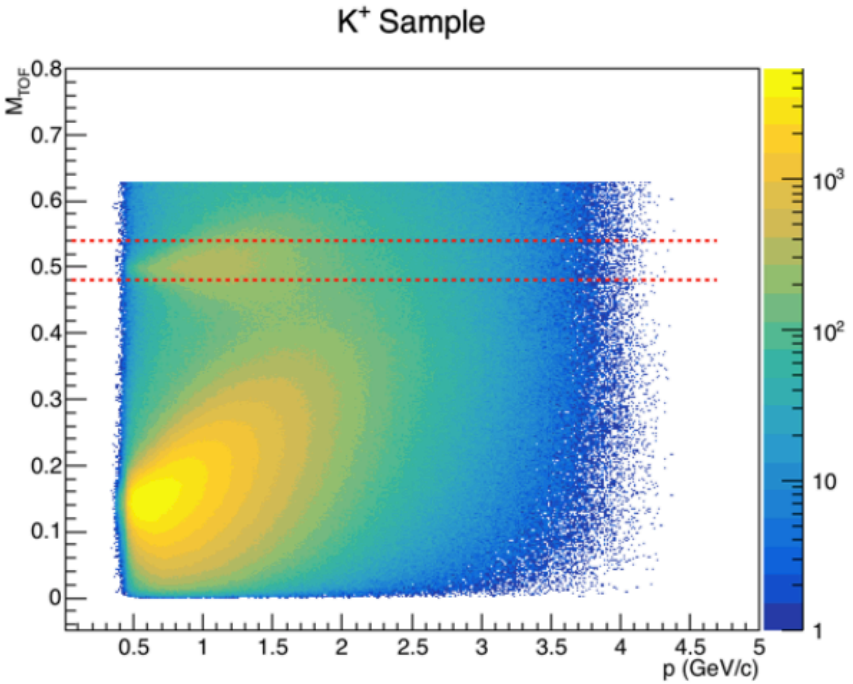
David Riser in collaboration with
Kyungseon Joo, Nick Markov

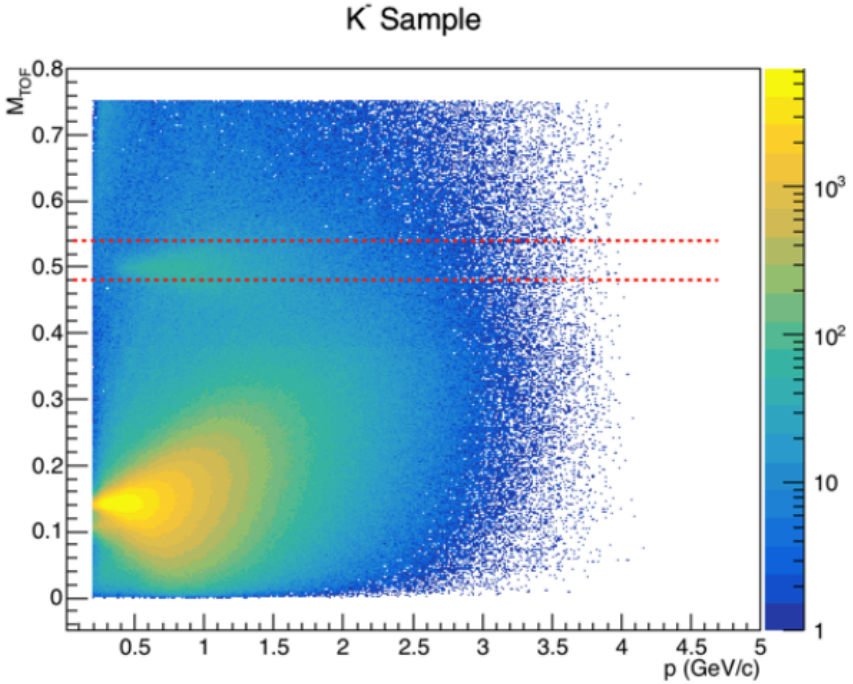
Select from data:

$$e\,p \rightarrow e'\,K^{\pm}X$$

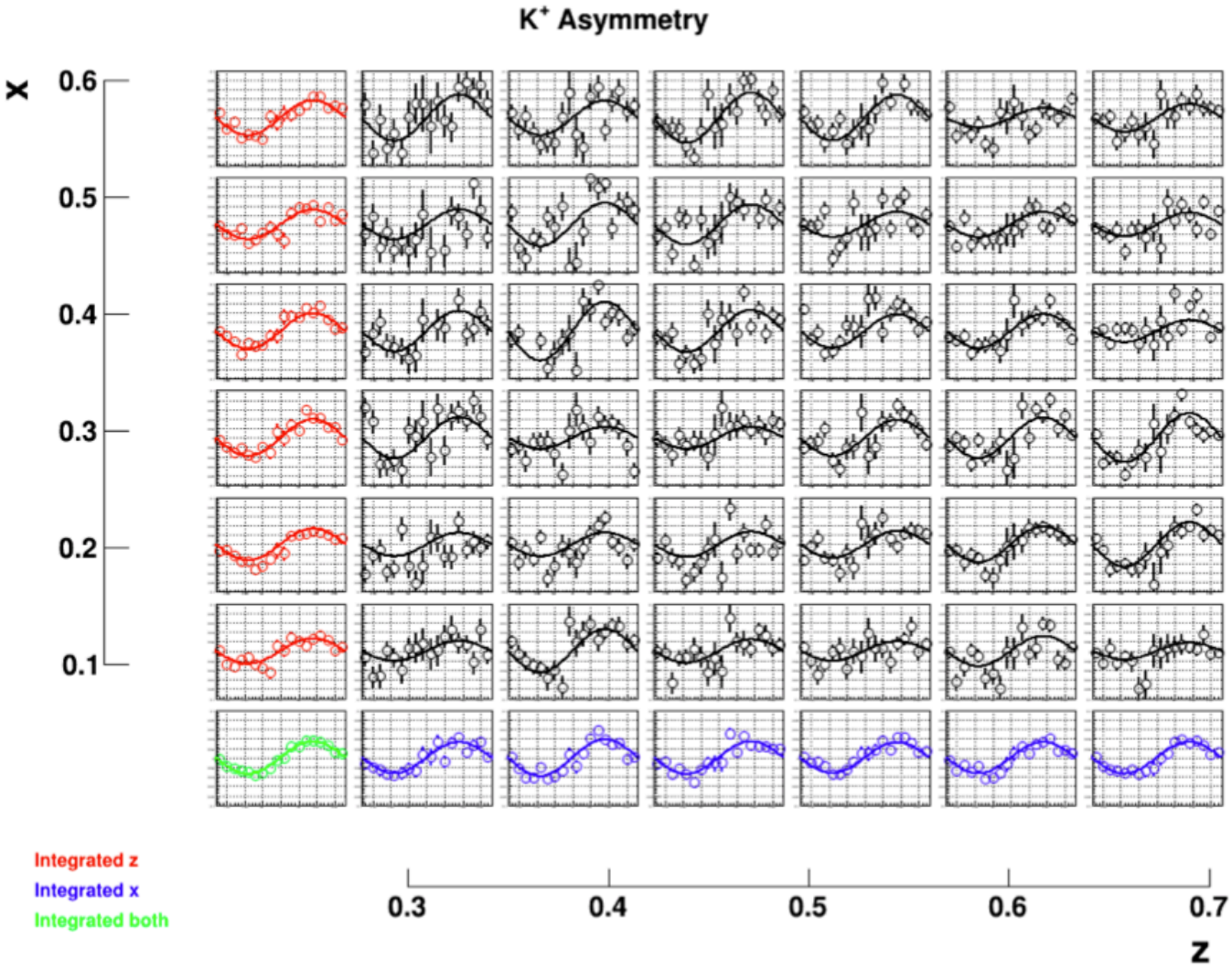
final selection done with timing cut on time of flight mass

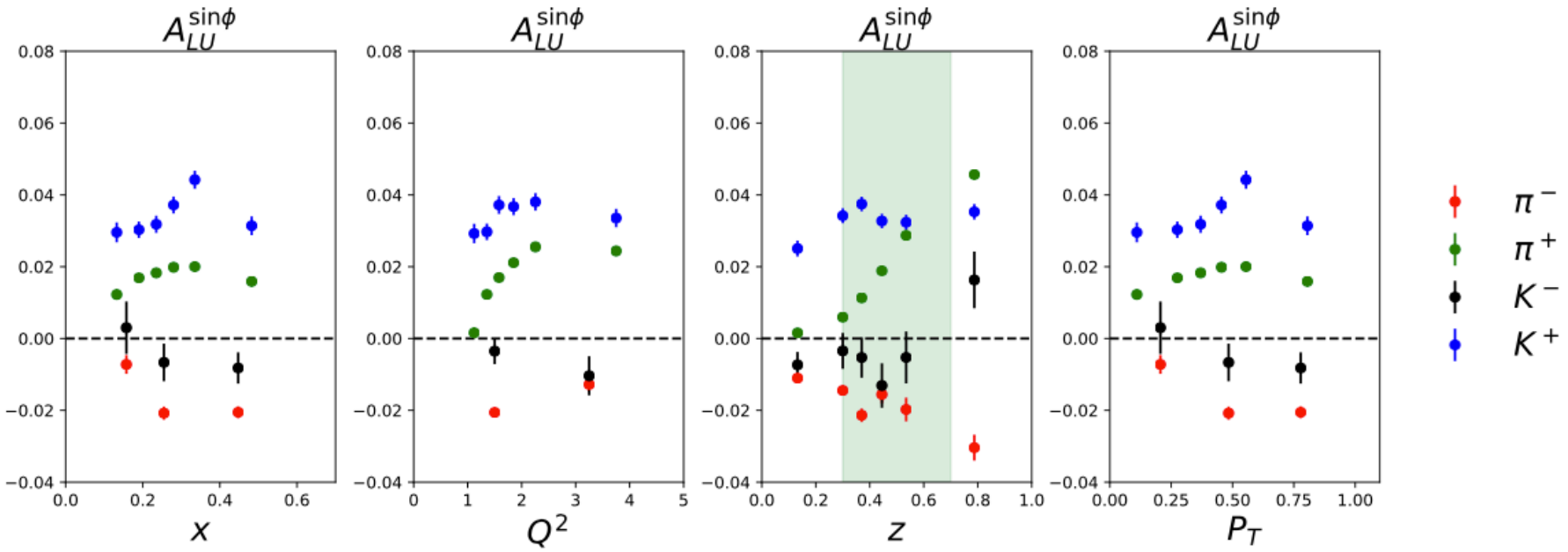
$$M^2_{TOF} = p^2\,\frac{1-\beta^2}{\beta^2}$$





observed asymmetry for positive **kaon** with same sign as positive pion



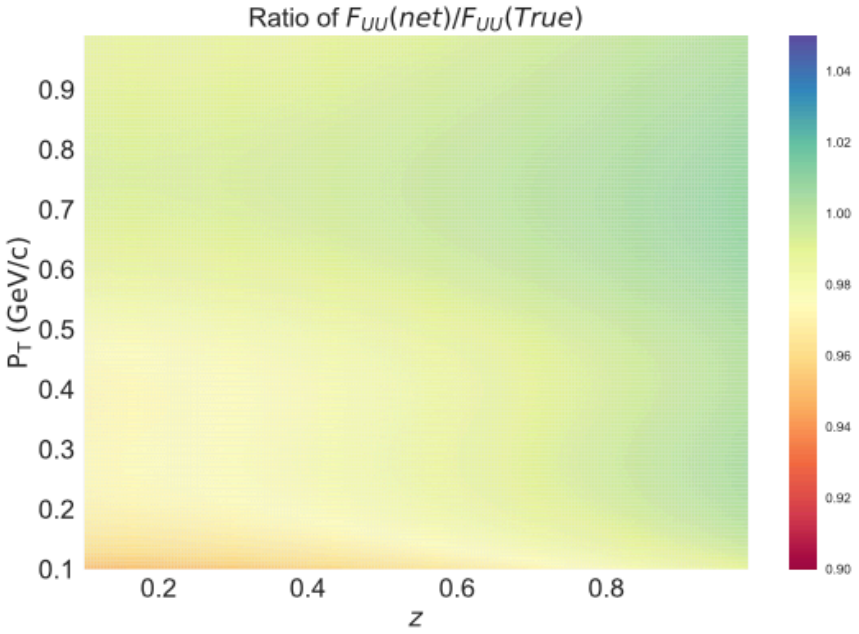

$A_{LU}^{\sin\phi}$
x
Q^2
z
P_T
π^-
π^+
K^-
K^+

3D PDF Extraction and VAlidation framework (EVA)

Nobuo Sato
University of Connecticut
CLAS Collaboration Meeting, Jefferson Lab, 2017

- **New analsys framework for TMDs**

- Implementation of all 18 SFs using WW-approx
- Neural Nets representation of SFs
- TMD extraction package



1) Structure functions (SFs) library

- Generic interface to SFs
- Implementation of the 18 SIDIS SFs
- SFs to neural nets for SFs with slow performance

2) MCEG

- Sampling methods:
  - Vegas integrator
  - MCMC sampling
  - Nested sampling (nestle)
- Radiative corrections
- JSON format as ouput

3) Detector simulation

- Not part of this project
- JSON files as input
- JSON files as output

4) TMD extraction

- JSON format as input
- Likelihood analysis
  - Least squares minimization
  - Iterative Monte Carlo (IMC)
  - MCMC sampling (HMC)
  - Nested sampling (nestle)

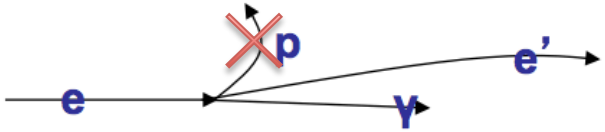
Studies of e'γX and of e'π0X with clas and clas12

Harut Avakian

DeepPWG meeting , JLab, June 15, 2017

- First measurements could be performed using only identified electrons and photons (e'X, e'π^0X, e'γX)

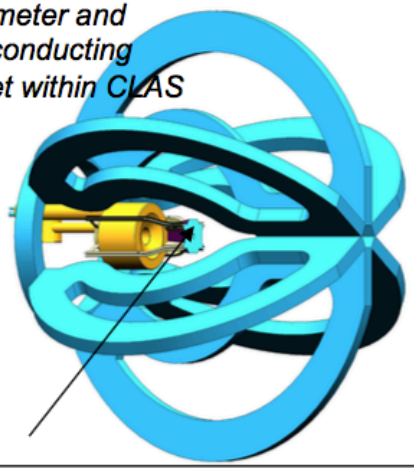
CLAS e1DVCS2 experiment



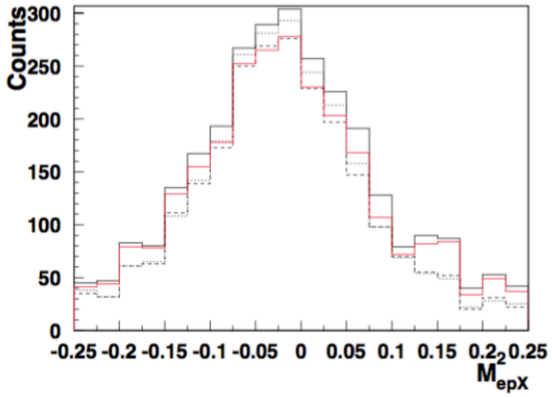
→ Less background than in e1dvcs
→ Large kinematical coverage in x_B and t (higher E_b)

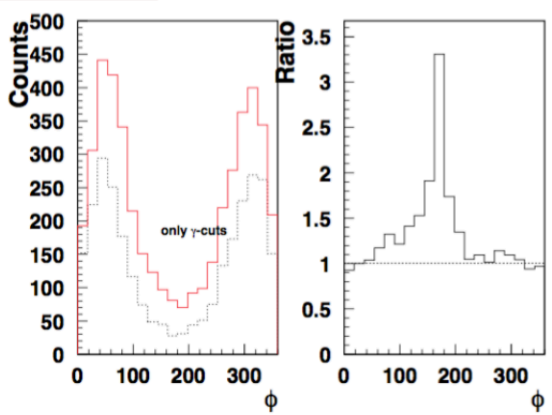
CLAS@5.9 GeV

Calorimeter and superconducting magnet within CLAS torus



dedicated calorimeter (424 PbWO4 crystals) detect photons from 5°-15°



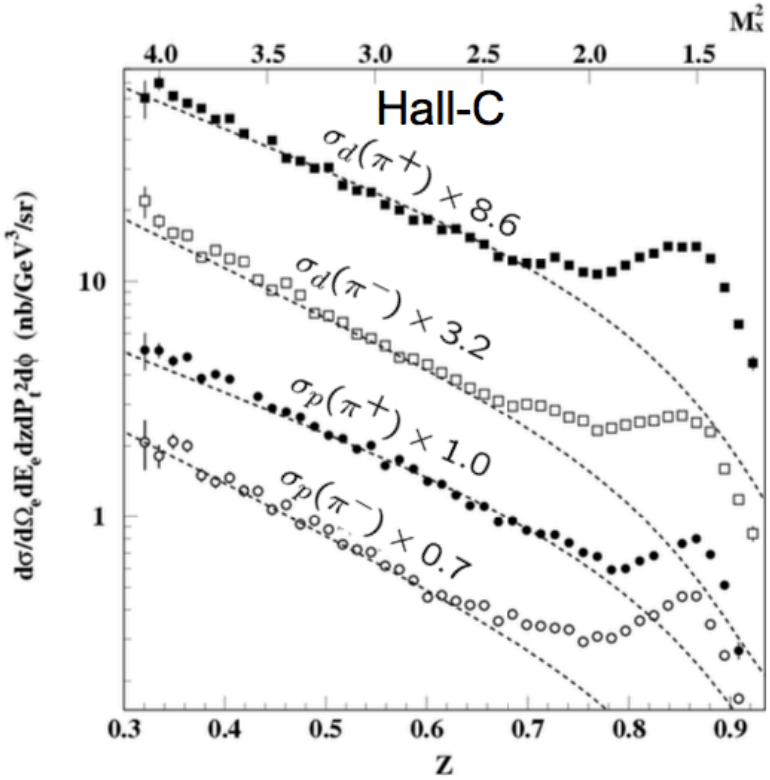


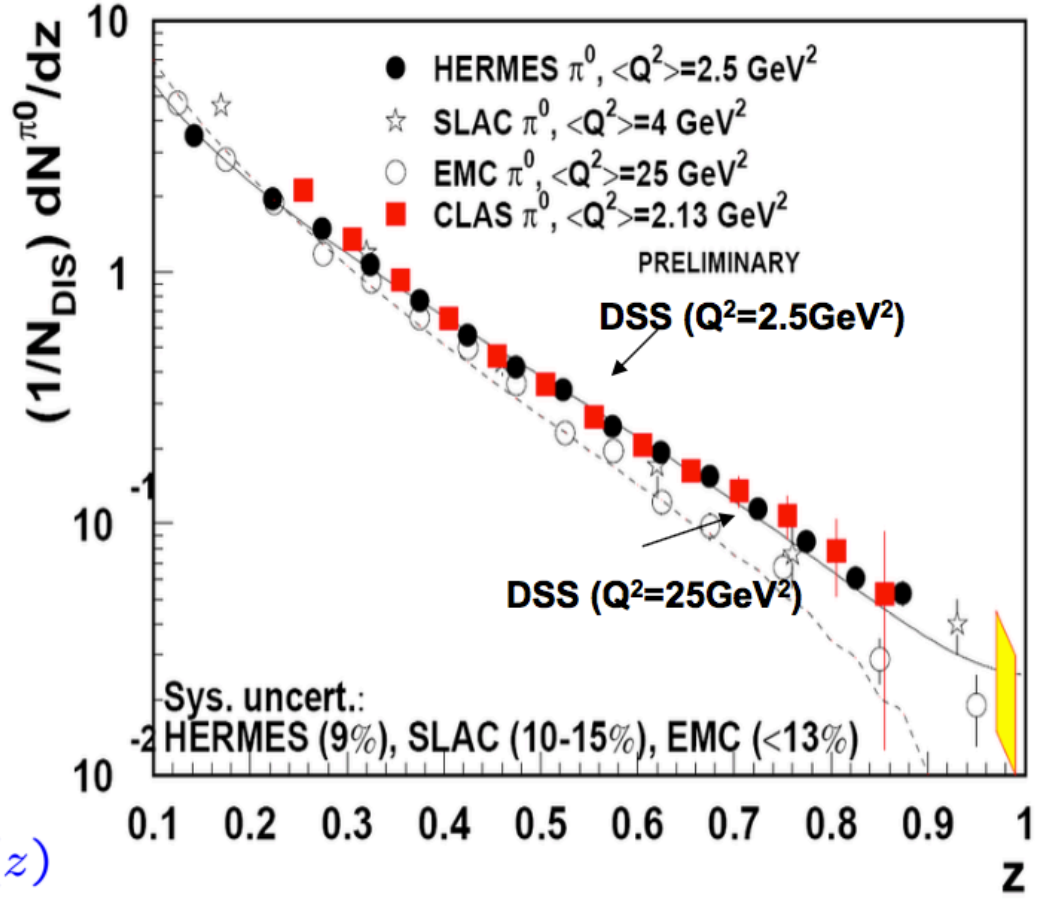
Cuts on photon missing mass, minimum energy and the angle between γγ*, may be sufficient, but will require good MC simulation to understand better the background around 180 degrees, where p0 contribution may be significant.

DVCS studies with just e' and γ are feasible and require only detailed understanding of the photon acceptance (+MC)

Use e1dvcs2 data to study feasibility of DVCS/BH studies with only electron and photon detection!

π multiplicities in SIDIS ep→e'πX





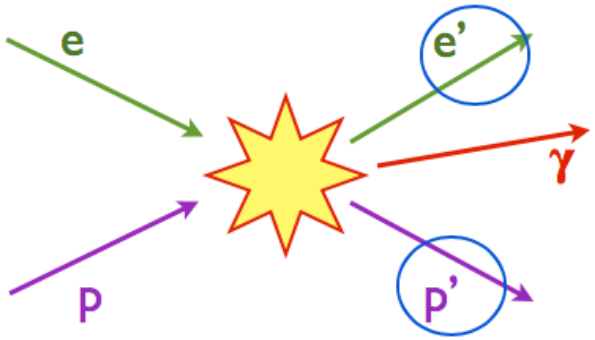
$$d\sigma^h \propto \sum f^{H\to q}(x)\,\mathrm{d}\sigma_q(y)\,D^{q\to h}(z)$$

π^0 multiplicities less affected by higher twists
0.4<z<0.7 kinematical range, where higher twists are expected to be small

Status of DVCS Analysis from E1-6 Data

A. Movsisyan, H. Avakian, S. Pisano

INFN-Ferrara

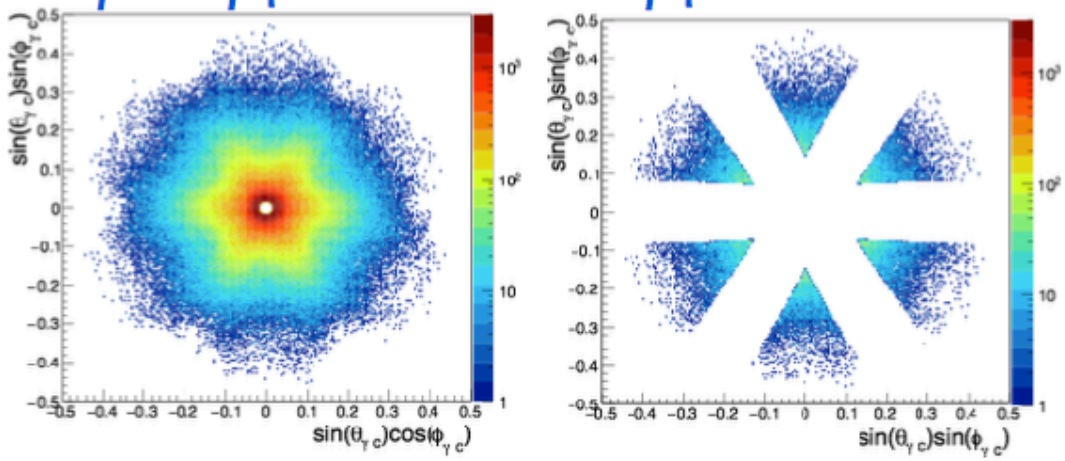


E1-6 experiment:

Data collected in 2001-2002.
Beam energy 5.754 GeV
5cm long liquid hydrogen target
Average beam polarization 70%

spatial distributions of calculated photons

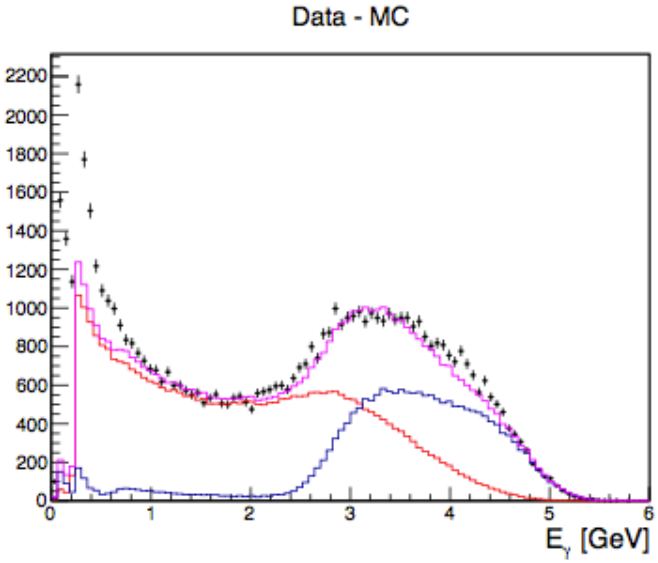
ep & epγ *epγ*



Exclusive photons ($ep\gamma$ sample)

Data - MC comparison exclusive photons:

$$W^2 > 4\ [GeV^2]$$
$$0.07 < -t < 0.52\ [GeV^2]$$
$$|M_X^2(epX)| < 0.08\ [GeV^2]$$
$$P_{ele.} > 0.7\ [GeV]$$
$$t < t_{min}$$
$$\theta_{\gamma calc.} > 2^\circ$$

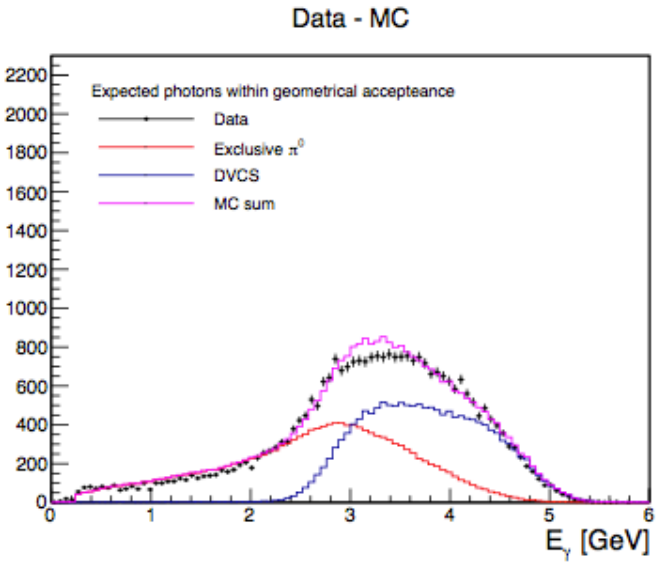


Low energy photon tail is not reproduced in simulation

In case of $ep\gamma$ sample can be removed by additional exclusivity cuts.

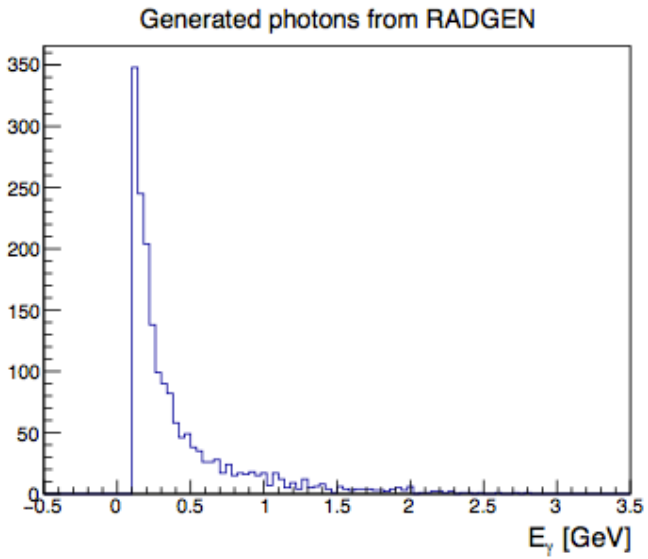
The origin should be understood to avoid problems in ep sample

Possible candidate could be radiative hard photons (currently missing in the MC)

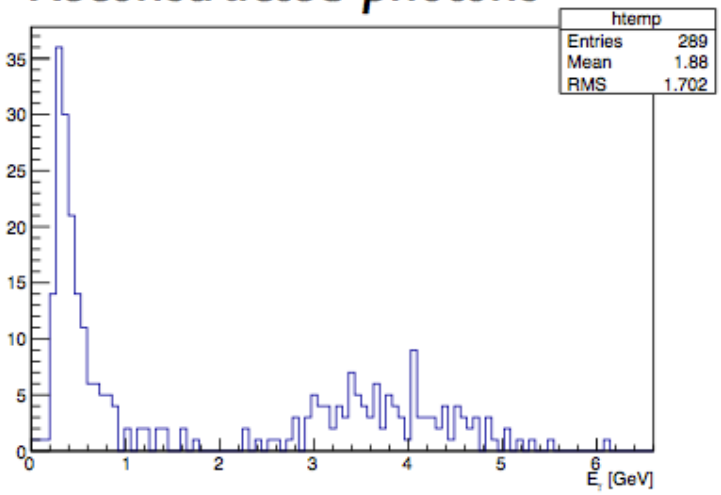


DVCS+RADGEN

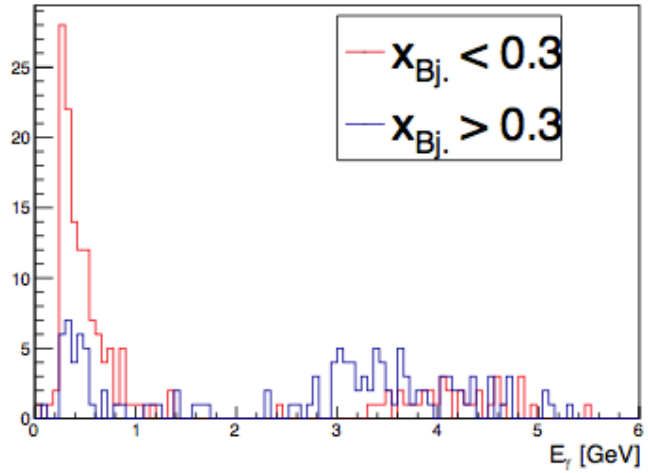
RADGEN 2.0 package is used with DVCS generator
Originally designed for inclusive DIS.
Can be used to study the shape of photon energy spectra.
Indication of strong xB dependence



Reconstructed photons

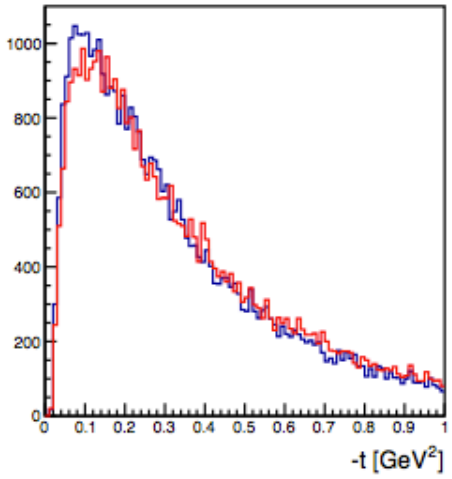


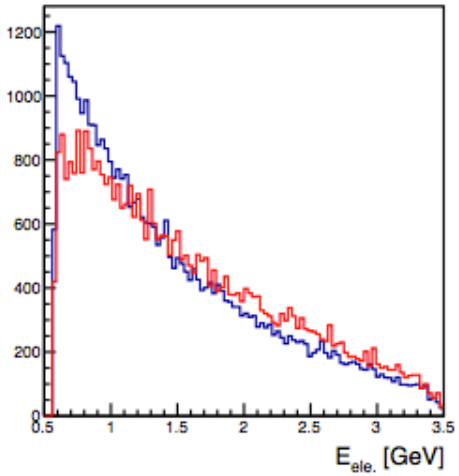
Reconstructed photons

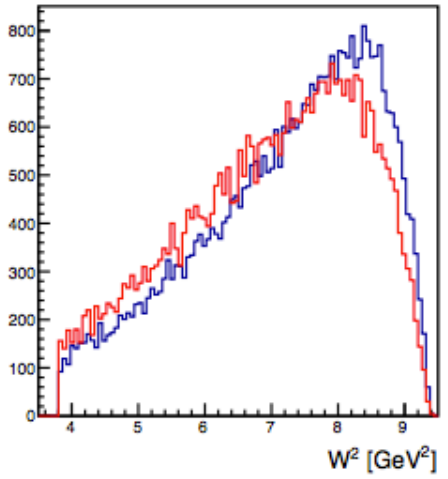


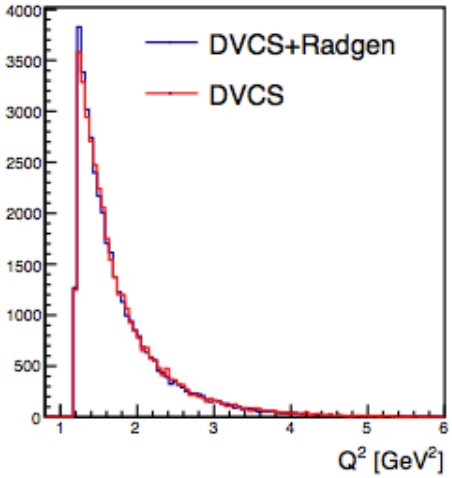
DVCS+RADGEN

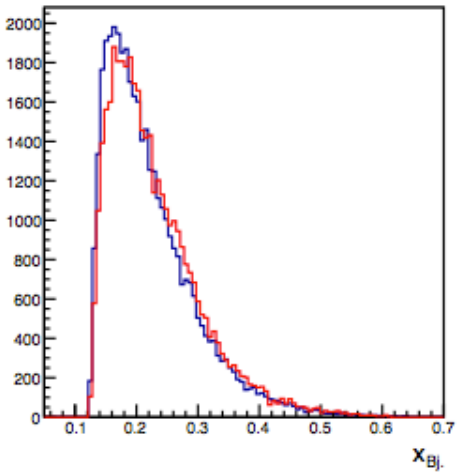
Non negligible event migration in generated event sample

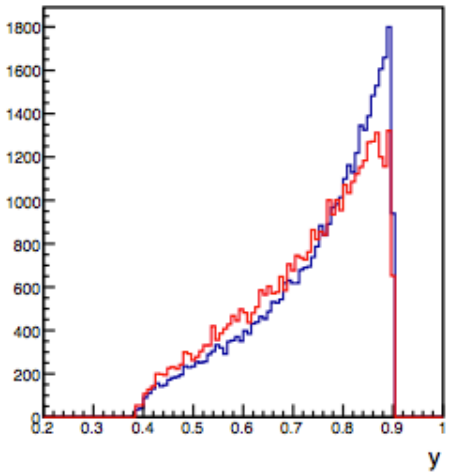












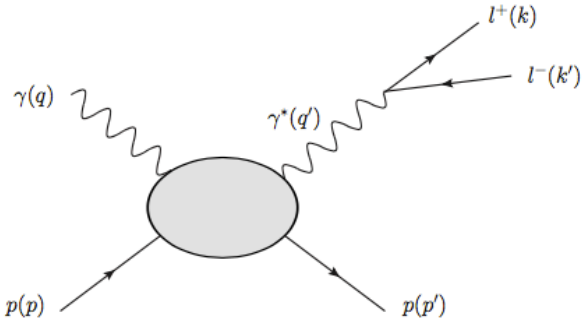
A. Movsisyan

TCS AT CLAS12

INFN-Ferrara

Timelike Compton Scattering

Complementary probe of GPDs
Sensitivity to the real part of CFF H
Can be used to test the universality of GPDs



Request from Hall C colleagues: T.Horn and V.Tadevosyan
Evaluate the figure of merit for TCS on transversely polarized target

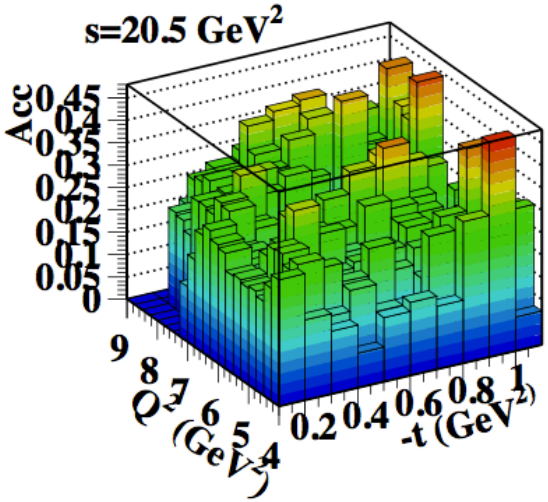
Evaluate the acceptance for TCS, using complete chain of simulation + reconstruction within CLAS12 software (GEMC + COATJAVA)

Approved proposal for CLAS12 on an unpolarized proton

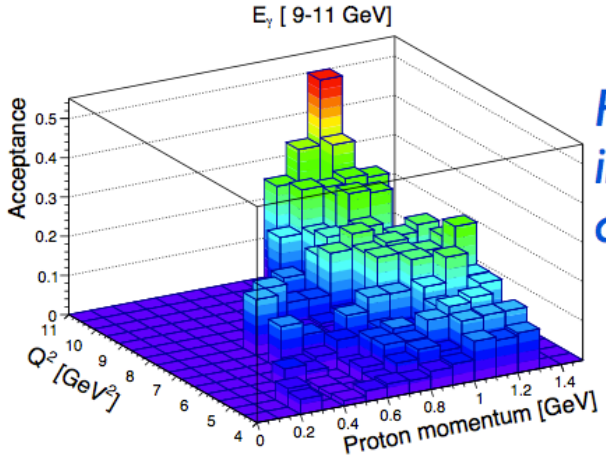
Jefferson Lab PAC 39 Proposal
Timelike Compton Scattering and J/ψ photoproduction on the proton in e^+e^- pair production with CLAS12 at 11 GeV

I. Albayrak,[1] V. Burkert,[2] E. Chudakov,[2] N. Dashyan,[3] C. Desnault,[4] N. Gevorgyan,[3] Y. Ghandilyan,[3] B. Guegan,[4] M. Guidal*,[4] V. Guzey,[2,5] K. Hicks,[6] T. Horn*,[1] C. Hyde,[7] Y. Ilieva,[8] H. Jo,[4] P. Khetarpal,[9] F.J. Klein,[1] V. Kubarovsky,[2] A. Marti,[4] C. Munoz Camacho,[4] P. Nadel-Turonski*†,[2] S. Niccolai,[4] R. Paremuzyan*,[4,3] B. Pire,[10] F. Sabatié,[11] C. Salgado,[12] P. Schweitzer,[13] A. Simonyan,[3] D. Sokhan,[4] S. Stepanyan*,[2] L. Szymanowski,[14] H. Voskanyan,[3] J. Wagner,[14] C. Weiss,[2] N. Zachariou,[8] and the CLAS Collaboration.

Acceptance from PAC 39
s=20.5 GeV



Acceptance for a kinematic bin
E_γ [9-11 GeV]

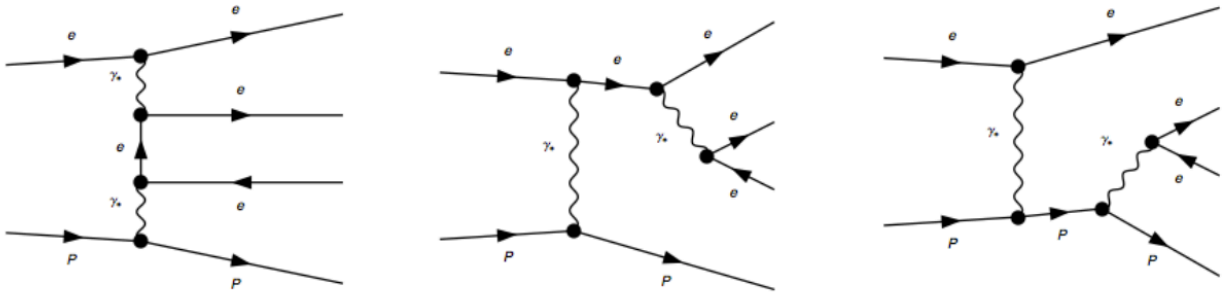


Results for acceptance calculation in various kinematic bins are consistent with PAC 39.

Using the CLAS12 Analysis Framework to Analyze CLAS6 Data

Timothy B. Hayward

Looking for lepton-trident events ($e^- + p \rightarrow e^{-\prime} + e^- + e^+ + p'$).

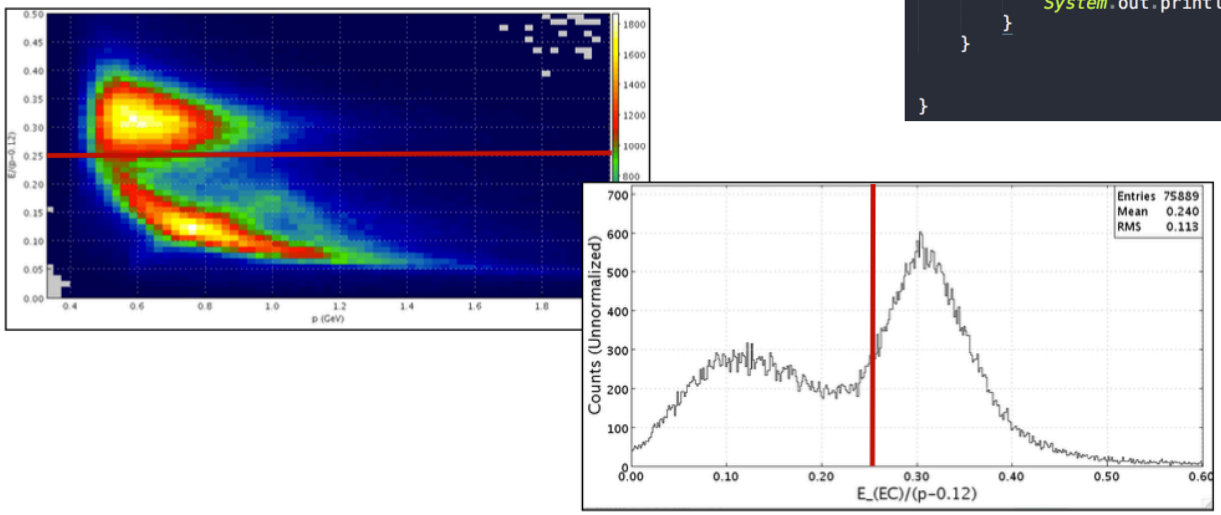


- Use CLAS12 software to develop kinematic fitter based on previously developed cuts to pick out trident events from eg1-dvcs data.

```java
public static void main(String[] args) {

    HipoDataSource reader = new HipoDataSource();
    reader.open("/volatile/clas12/thayward/eg1dvcs_data/temp/hipo/run_58799_pass1.a00");
    GenericKinematicFitter fitter = new fitter_A(5.887);
    EventFilter filter = new EventFilter("11:2212");

    while(reader.hasEvent()==true){
        HipoDataEvent event = reader.getNextEvent();
        PhysicsEvent  recEvent  = fitter.getPhysicsEvent(event);

        if(filter.isValid(recEvent)==true){
            Particle mx = recEvent.getParticle("[b]+[t]-[11]-[2212]");
            System.out.println(mx.e());
        }
    }


}
```

Where the work gets done!

Positron Cuts – EC Energy



- All relevant CLAS6 banks and event information included in the bos2hipo converter.
- Now possible to analyze CLAS6 data using the new CLAS12 Java framework.
- Contact: tbhayward@email.wm.edu

BACKUP

PAC Days
Boldface = days designated High Impact
Parentheses = days not counting toward High Impact total

PAC41 "High Impact" Selection

Row Color
Yellow = High Impact
Green = backup expt

Exp#	Exp name	Hall	Run Group/ Days	PAC Days	PAC grade	Comments
	TOPIC 3 : PDFs					
E12-06-113	**BONuS** : The Structure of the Free Neutron at Large x-Bjorken	**B**	F/40	(40) approved **★21** ↓	A	Requires BONuS Radial TPC upgrade **★42 days High Impact for the experiment**
E12-10-103	**MARATHON** : Measurement of the F2n/F2p, d/u Ratios and A=3 EMC Effect in DIS off the Tritium and Helium Mirror Nuclei	**A**	Tritium target group/61	↑ **★21** (42) approved	A	**that runs first; experiments are equally important & both are essential**
E12-06-110	**A1n HallC–3He** : Meas of Neutron Spin Asymmetry A1n in the Valence Quark Region Using an 11 GeV Beam and a Polarized 3He Target in Hall C	**C**		**36**	A	Requires high luminosity 3He
	TOPIC 4T : TMDs					
C12-11-111	**TMD CLAS–HDIce** : SIDIS on Transverse polarized target	**B**	G/110	**110** concurrent	A	Requires transversely polarized HDIce with electron beam
C12-12-009	**Dihadron CLAS-HDIce** : Measurement of transversity with dihadron production in SIDIS with transversely polarized target	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-06-112	**TMD CLAS-H(Unpol)** : Probing the Proton's Quark Dynamics in Semi-Inclusive Pion Production at 12 GeV	**B**	A/139	(60) approved **★10**	A	Hall B commissioning + 10 days **★plus (50) commissioning days**
	TOPIC 4G : GPDs					
E12-06-114	**DVCS HallA–H(UU,LU)** : Measurements of Electron-Helicity Dependent Cross Sections of DVCS with CEBAF at 12 GeV	**A**	Early: DVCS & GMp/62	(100) approved **★70**	A	Hall A commissioning
C12-12-010	**DVCS CLAS–HDIce** : DVCS at 11 GeV with transversely polarized target using the CLAS12 Detector	**B**	G/110	(**110**) concurrent	A	Requires transversely polarized HDIce with electron beam C1 Proposal
E12-11-003	**DVCS CLAS–D(UU,LU)** : DVCS on the Neutron with CLAS12 at 11 GeV	B	B/90	(90) approved	A	Requires D target; central neutron detector ready in 2016 **★Backup GPD-E meas if HDIce delayed**