RUN GROUP A - Experiments

Duration: 139 days

20 days commissioning
60 days high luminosity
39 days low luminosity
20 days reversed torus polarity

Energy: 11 GeV
Target: LH2

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					

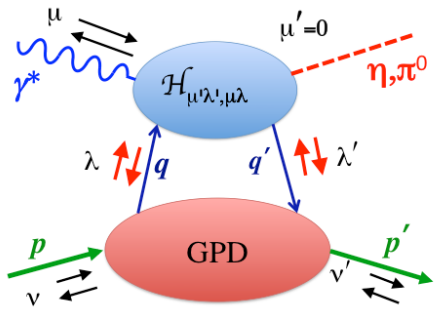
Possible RG Schedule (straw man)

Run Group	Days	2016	2017	2018	2019	2020	2021	2022	Remain
All Run Groups	**1036**#)	30	15	95	105	105	105	105	456
HPS	180*	15		35	10	10	10	10	90
PRad	15*	15							0
CLAS12 Comm			3 15						0
RG-A + RG-K (proton)	239*		10	20/15 25		35	20		114*
RG-B (deuteron)	90*				40				50*
RG-F (BoNuS)	42*				21				21
RG-C (NH_3)	120				35	25			60
RG-C-b (ND_3)	65					35			30
RG-E (Hadr.)	60						35		25
RG-H (Transv. Target)	110*						40	20	50
RG-D (CT)	60							40	20
RG-G (LiD)	55							35	20

#) incl. RG-H

E12-06-108 Hard exclusive π0 and η electroproduction with CLAS12

P. Stoler,
K. Joo,
V. Kubarovsky,
M. Ungaro,
C. Weiss



Quark helicity flip

Kroll, Goloskokov
Goldstein Liuti

Transversity GPDs

Generalized form factors "GFF"

Nucleon GFFs

$|\langle \bar{E}_T \rangle|^2 \propto \frac{1}{t}\sigma_{TT}$

$|\langle H_T \rangle|^2 \propto [\sigma_T + \sigma_{TT}]$

$\sigma_T \gg \sigma_L$

Quark flavor GFFs:

$\langle E_T^u \rangle \propto \langle E_T^\pi \rangle + \sqrt{3}\langle E_T^\eta \rangle$

$\langle E_T^d \rangle \propto \langle E_T^\pi \rangle - \sqrt{3}\langle E_T^\eta \rangle$

Similarly for H_T

Physics objectives

- Quantify approach to small-size regime in exclusive π0, η production at $Q^2 > 1$ GeV^2
- Extract GFFs containing **quark transversity GPDs** and perform flavor separation

Observables and analysis

- Differential cross section dσ/dt: Q^2, *W,* t-dependence for reaction mechanism, size
- L/T information from **φ-dependent structure functions** sufficient because $\sigma_T >> \sigma_L$, Rosenbluth separation not needed!
- Method successfully demonstrated with 6 GeV data

Impact and significance

- Unique access to quark transversity: chiral symmetry breaking, lattice QCD

E12-06-108A Exclusive N* → KY Studies CLAS12

D.S. Carman,
R. Gothe,
V. Mokeev

- Measure exclusive $K^+\Lambda$ and $K^+\Sigma^0$ electroproduction cross sections (and to extract the separated structure functions) from an unpolarized proton target with a longitudinally polarized electron beam using the CLAS12 spectrometer.

  E_b = 11 GeV, Q^2 = 3 – 12 GeV^2, W = 1.6 – 3.0 GeV, cos θ_K = [-1:1]*

- Key Motivations:
  - *Extract γ_vNN* electrocouplings for high-lying N* states that couple to KY vs. Q^2*
    - *Important source of information on still poorly determined N* → KY hadronic decays*
    - *Important independent check of electrocouplings derived from CLAS12 N$\pi\pi$ data*
  - *Provide information on KY electroproduction amplitudes at distance scales that correspond to the transition from meson-baryon to quark-gluon degrees of freedom*
  - *Enhance capabilities to search for new states of hadronic matter ("missing" N*'s, hybrid baryons)*

- A dedicated experiment to study N* structure in the electroproduction of exclusive non-strange (Nπ, N$\pi\pi$) final states with CLAS12 has already been approved (E12-09-003).

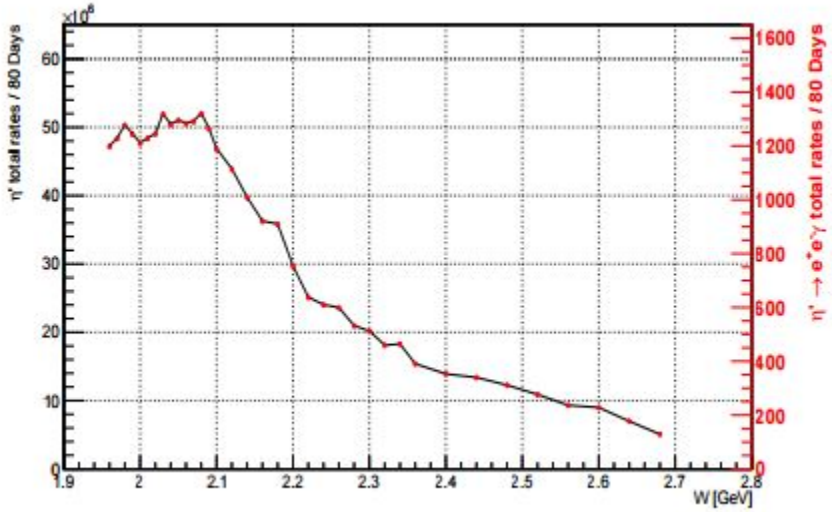
The KY experiment results in a more complete N program with CLAS12*

E12-06-108B Transition Form Factor of the η' Meson with CLAS12

M. C. Kunkel
D. Lersch

From previous CLAS analyses using the g12 data set, it was shown that measurements of the time-like transition form factor were achievable, but without the statistical precision needed to be competitive.

Therefore, we propose to use CLAS12 to measure the Dalitz decay channel of the reactions ep → e'p η' , where η' → e +e −γ, through detection of the final state proton and η' decay products. Preliminary studies using the CLAS12 simulation suite have shown that a beam time of **80 days, at full luminosity**, will accumulate a data sample at least one order of magnitude larger in statistics than the most current η' → e +e −γ measurement and would yield a statistical uncertainty . 0.5%



Total η' production rate per 80 days (left y-axis) and total η' → e +e −γ rates per 80 days (right y-axis) as a function of W

E12-06-112 Proton's quark dynamics in semi-inclusive pion production at 11 GeV

H.Avakian, M.Contalbrigo, Z.Meziani, B. Seitz, K.Joo

$$\frac{d\sigma}{dx_B\,dy\,d\psi\,dz\,d\phi_h\,dP_{h\perp}^2} = f_1 \otimes D_1 \quad \text{(HT)}$$

$$\frac{\alpha^2}{x_B y Q^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x_B}\right)\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} \quad \text{(HT)}$$

$$+ \varepsilon\cos(2\phi_h) F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\Big\},$$

$h_1^\perp \otimes H_1^\perp$ (HT)

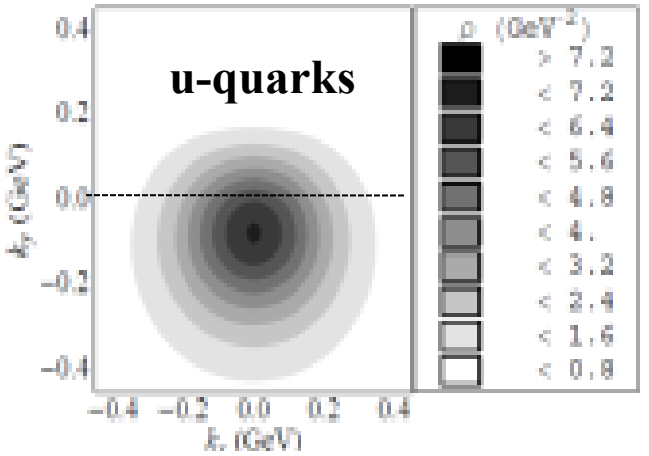
N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1 h_{1T}^\perp$

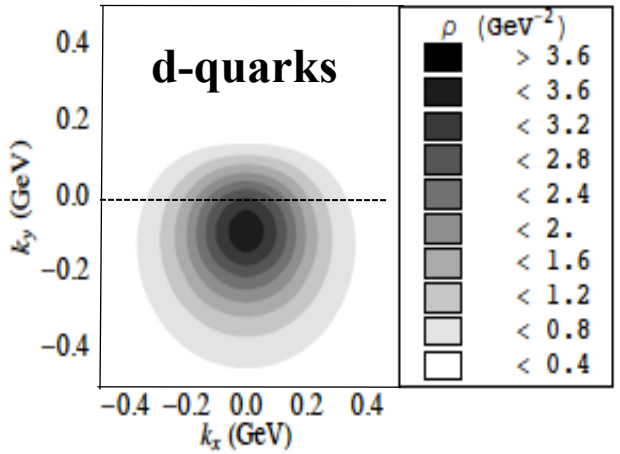
BM TMD (1998) describes correlation between the transverse momentum and transverse spin of quarks, requires FSI or ISI

$$f_{q/p}(x,k_\perp^2) = \frac{1}{2}[f_1^q(x,k_\perp^2) - h_1^{\perp q}(x,k_\perp^2)\frac{(\hat{P}\times k_\perp)\cdot S_q}{M}]$$

$$h_1^{\perp q}(SIDIS) = -h_1^{\perp q}(DY)$$

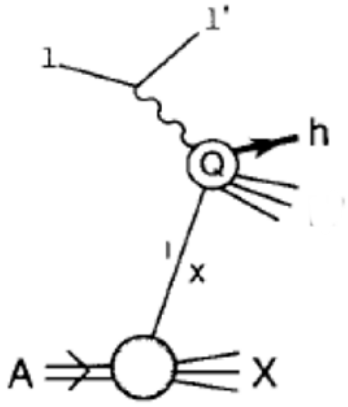
BM TMD under intensive studies worldwide, including SIDIS and DY experiments, model calculations, lattice simulations.





M. Mirazita

Semi-Inclusive production of hadrons e p → e h X

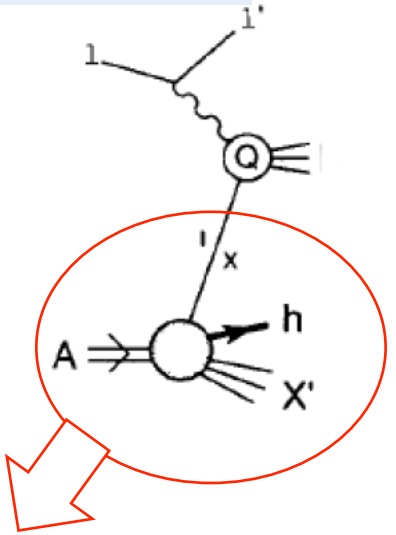


Current Fragmentation Region, CFR

- **h is produced by the struck q**

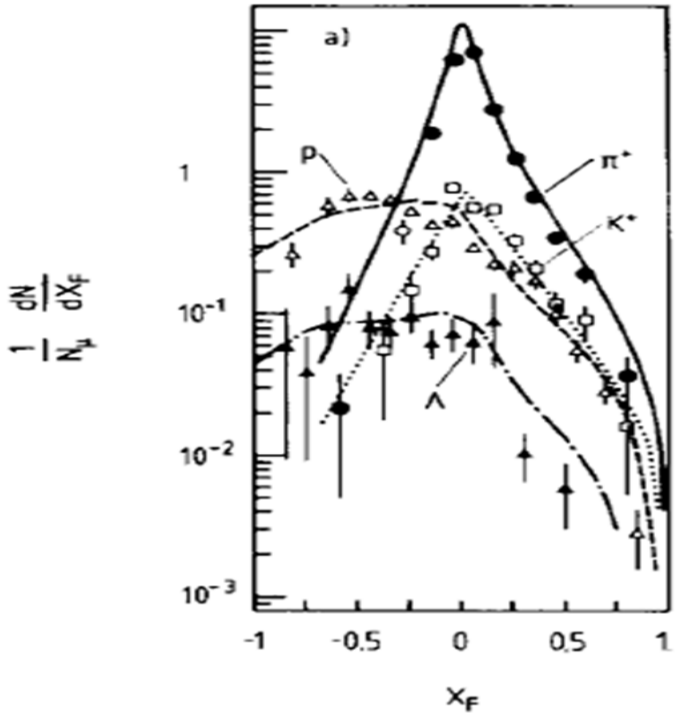
Target Fragmentation Region, TFR

- **h is produced by the nucleon remnants**



Fracture Function

- **probability to produce a hadron h when the quark of type i is hit by the virtual photon**

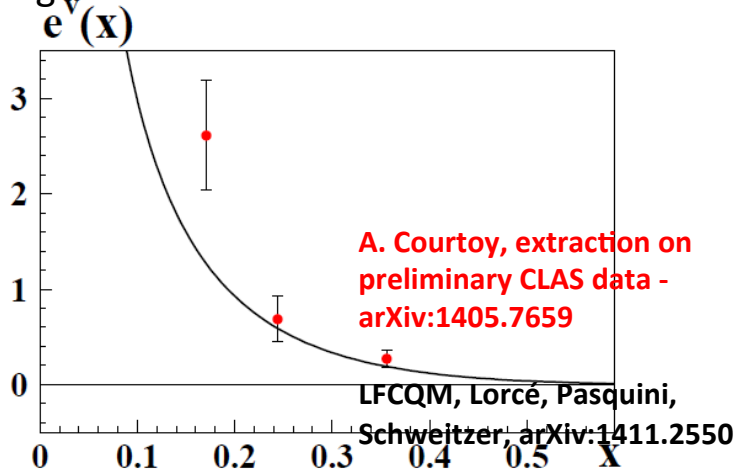


- **TFR is the dominant baryon production mechanism at backward angles**
- **It may still contribute at forward angles**
- **TFR/CFR separation needs to be understood**

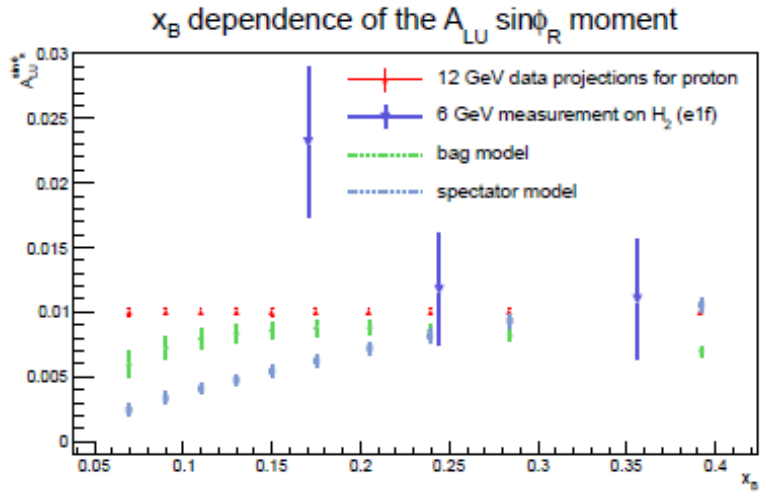
E12-06-112B/E12-09-00 Higher-twist collinear structure of the nucleon through di-hadron SIDIS on unpolarized hydrogen and deuterium.

S. Pisano

Higher-twist 1D Parton Distribution Function $e(x)$ offers important insight into the quark-gluon correlations, and its integral is related to the *scalar charge* of the nucleon and to the nucleon-pion sigma term



- Di-hadron SIDIS Beam-Spin Asymmetry represents the cleanest observable to access $e(x)$
- 6-GeV results on $A_{LU}^{\sin\phi_R}$ led to a first extraction of $e(x)$
- combined measurement on hydrogen and deuterium will allow to perform a *flavor separation* to access $e^{u}(x)$, $e^{d}(x)$
- measurement at 11 GeV will extend the kinematics of the 6-GeV analysis, and will improve dramatically its precision

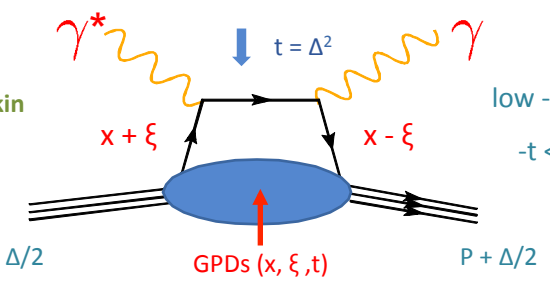


E12-06-119 Deeply Virtual Compton Scattering with CLAS12

F. Sabatie
A. Biselli
H. Egiyan
L. Elouadrhiri
M. Holtrop
D. Ireland
W. Kim

Q_{hard}^2 large

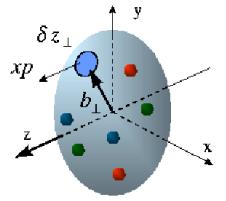
Mueller, Ji, Radyushkin (94-96)

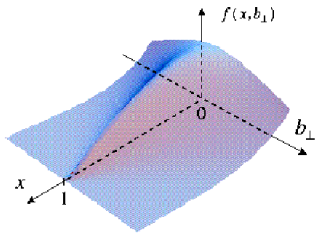


Mostly H for unpolarized proton target

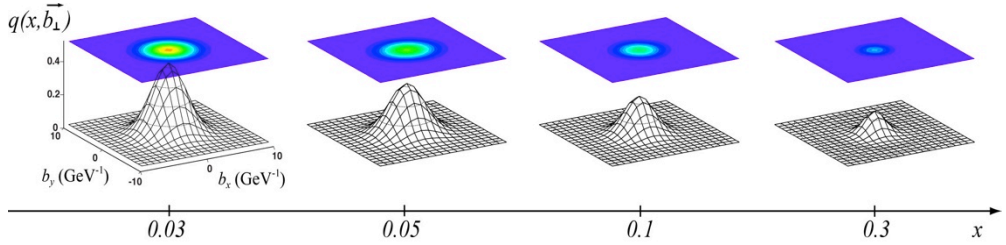
low -t process :

$-t << Q_{hard}^2$





$$q(x,\vec{b}_\perp) = \int \frac{d^2\vec{\Delta}_\perp}{(2\pi)^2} e^{i\vec{b}_\perp\cdot\vec{\Delta}_\perp} H(x,\xi=0,-\Delta_\perp^2)$$



The DVCS amplitude is expressed in terms of Compton Form Factors (CFF) at LO:

$$\mathcal{H}(\xi,t) = \sum_q e_q^2 \left\{ i\pi \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right] + \mathcal{P}\int_{-1}^{+1} dx \left[\frac{1}{\xi - x} - \frac{1}{\xi + x}\right] H^q(x,\xi,t)\right\}$$

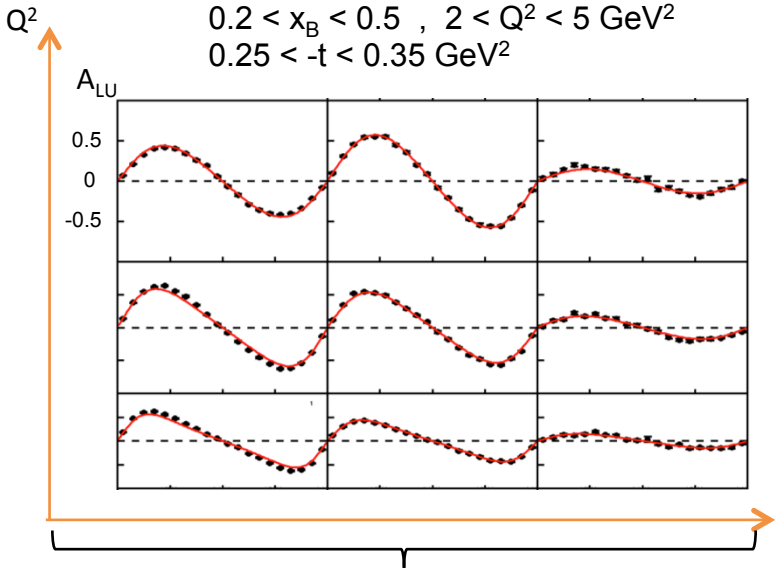
(similarly for other GPDs)

By measuring Beam and Target Spin Asymmetries, and through an harmonic analysis, one may extract Imaginary and Real parts of CFF :

$$A = \frac{d\sigma^{\leftarrow} - d\sigma^{\rightarrow}}{d\sigma^{\leftarrow} + d\sigma^{\rightarrow}} \simeq \Gamma_A(x_B, Q^2, t) \frac{\boxed{s_1^I}\sin\phi + s_2^I \sin(2\phi)}{\kappa c_0^{BH} + c_0^I + (\kappa c_1^{BH} + c_1^I)\cos\phi}$$

$$\boxed{s_{1,unp}^I} = y(2-y)\,\mathrm{Im}\left\{\boxed{F_1\mathcal{H}} + \frac{x_B}{2-x_B}(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right\}$$

CLAS12 pseudo-data sample in :
$0.2 < x_B < 0.5$, $2 < Q^2 < 5$ GeV^2
$0.25 < -t < 0.35$ GeV^2



Fit to CLAS6 or **CLAS12** A_{LU}

$\xi = 0$

Parametrized GPDs

GPD parametrization needed for ξ=0 or t=0 extrapolations

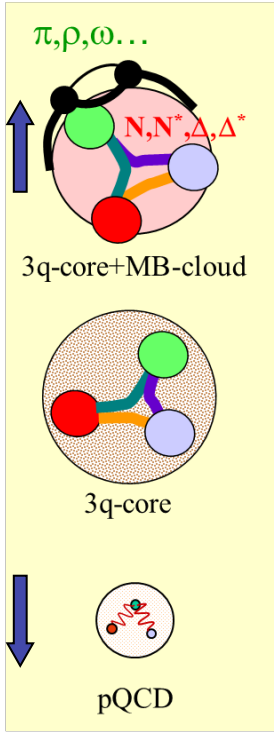
Lots of new developments in the next 5 years

E12-09-003 Nucleon Resonance Studies with CLAS12

R. Gothe
V. Burkert
P. Cole
K. Joo
V. Mokeev
P. Stoler

- CLAS12 will be only available facility worldwide capable of obtaining electro-excitation amplitudes for all prominent N* states from exclusive measurements of single meson, double pion, and KY electroproduction at still unexplored ranges from low photon virtualities down to 0.05 GeV^2 up to the highest photon virtialities ever achieved for exclusive reactions (5.0 GeV^2 <Q^2< 12 GeV^2).
- The expected results will allow at low Q^2 to
  - search for new states of hadronic matter - hybrid baryon,
  - extend the previous high-statitics analyses of exclusive meson photoproduction continuously to the new CLAS12 electroproduction data,

  and at high Q^2 to
  - probe quark distributions in excited baryons,
  - explore the dressed quark mass evolution at the distances where the transition from quark-gluon confinement to pQCD regime is expected, and thus addressing the most challenging problems of quark-gluon confinement and on the nature of 98% of the hadronic mass in the universe.



- The "Studies of the Excited Baryon Structure with CLAS12" will continue a productive and synergetic collaboration between experiment, phenomenology, and theory. This program will be very beneficial for Jefferson Lab since it will substantially contribute to the broad international efforts on the exploration of the strong interaction in non-perturbative regime and thus solidifying the US leadership in this important area, Int. J. Mod. Phys. E, Vol. 22, 1330015 (2013) 1-99.

M. Battaglieri
R. De Vita
C. Salgado
S. Stepanyan
D. Watts
D. Weygand

Meson spectroscopy with photons in CLAS12

Exp-11-005 "MesonEx"

Study the meson spectrum in the 1-3 GeV mass range to identify gluonic excitation of mesons (hybrids) and other quark configuration beyond the CQM

✳ **Hybrid mesons and Exotics**

- Search for hybrids looking at many different final states
- Charged and neutral-rich decay modes
- $\gamma p \rightarrow p\, 3\pi$, $\gamma p \rightarrow p\, \eta\, \pi$, ...

✳ **Hybrids with hidden strangeness and strangeonia**

- Intermediate mass of s quarks links long to short distance QCD potential
- Good resolution and kaon Id required
- $\gamma p \rightarrow p\, \phi\, \pi$, $\gamma p \rightarrow p\, \phi\, \eta$, $\gamma p \rightarrow p\, 2K\, \pi$, ...

✳ **Scalar mesons**

- Poorly know f_0 and a_0 mesons in the mass range 1-2 GeV
- Theoretical indications of unconventional configurations (qqqq or gg)
- $\gamma p \rightarrow p\, 2\pi$, $\gamma p \rightarrow p\, 2K$, ...

- Decay and production of exclusive reactions, different final states (charged/neutral)
- Detector requirements: good acceptance, energy resolution, particle Id
- Identification of exotic configuration via PWA

Requirements

1) High intensity 6-10 GeV photon beam
→ low Q^2 electroproduction

2) 4π detector
→ CLAS12 + Forward Tagger (FT)

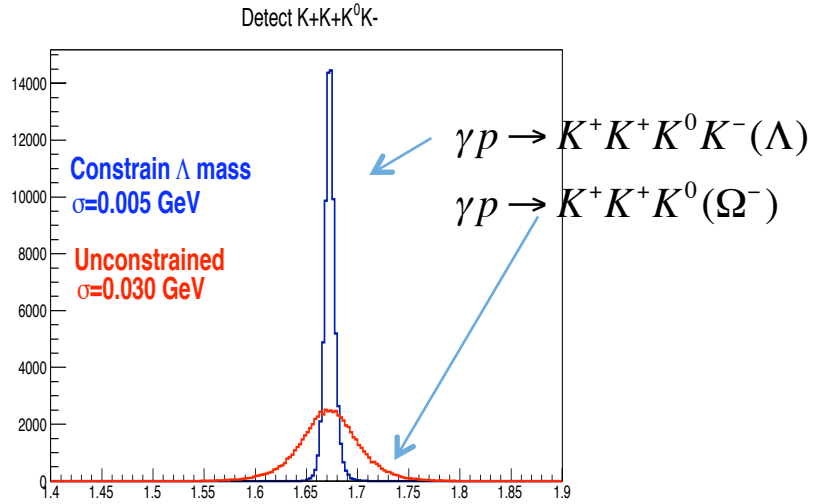
E12-11-005A Photoproduction of the very strangest baryons on a proton target in CLAS12

L. Guo
M. Dugger
J. Goetz
E. Pasyuk
I. Strakovski
D. Watts
N. Zachariou
V. Ziegler

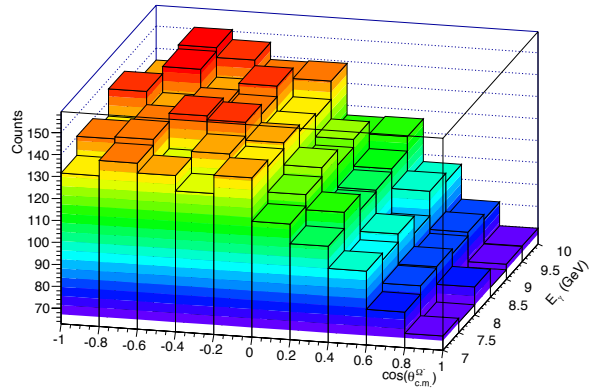
	Detected particles	Measured Decays	Overall Efficiency	Rate/hr	Total Detected
Ω^-	$K^+K^+K^0$		~3.9%	~3.6	~7k
Ω^-	$K^+K^+K^0K^-$	Ω^-	~0.5%	~0.5	~1k
Ξ^-	$K^+K^+\pi^-$	Ξ^-	~9.3%	~440	~0.9M
$\Xi^-(1530)$	$K^+K^+\pi^-$	$\Xi^-(1530)$	~7.4%	~140	~270K
$\Xi^-(1820)$	$K^+K^+K^-p$	$\Xi^-(1820)\Lambda$	~0.63%	~6	~12K

- Assuming half field and 80 beam days
- Vertex Efficiency/Branching Ratio included

•Ω^- photoproduction: Mass resolution



Expected Ω^- Cross section Measurements



E12-12-001 Timelike Compton Scattering and J/psi photoproduction on the proton in e+e- pair production

P. Nadel-Turonski
M. Guidal
T. Horn
R. Paremuzyan
S. Stepanyan

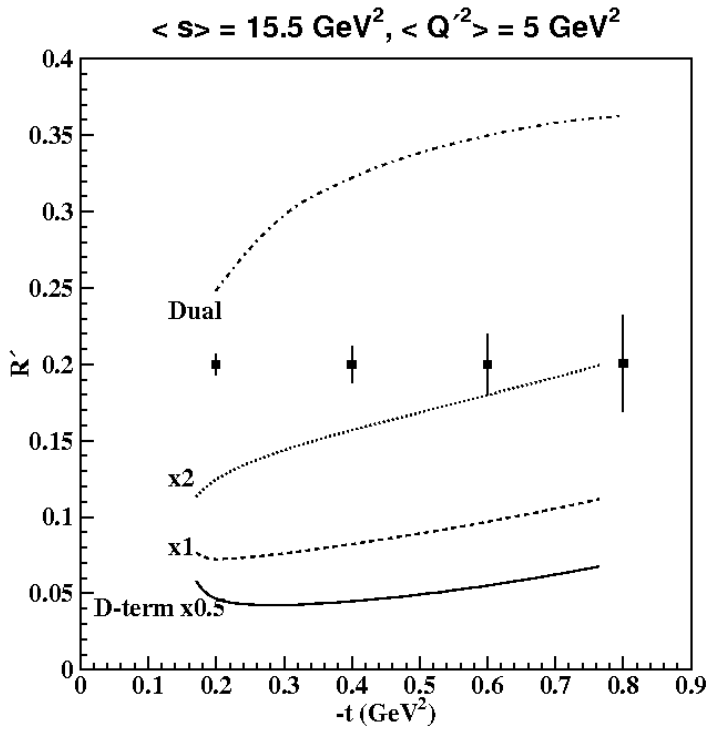
Approved for 100 days with the run group and 20 additional days **with reversed torus polarity**

Timelike-spacelike correspondence and the universality of GPDs

- Of fundamental importance for the GPD program
- Analogous to universality of PDFs in DIS and Drell-Yan

Compton Form Factor fits

- Combined fits of TCS and DVCS data significantly reduces uncertainty on CFFs compared with DVCS alone
- TCS moments are sensitive to the D-term
  - The figure shows statistical uncertainties in a rather wide bin of s and Q^2 for 100 days at a luminosity of 10^{35}. The lower curves show the double distribution with different values of the D-term (x1 is nominal).

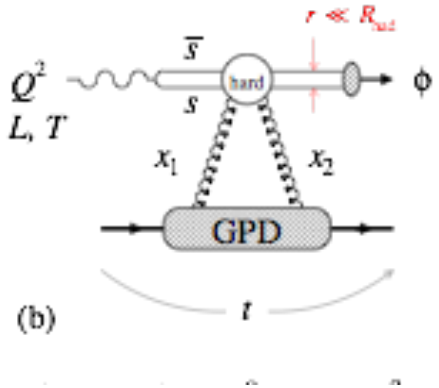


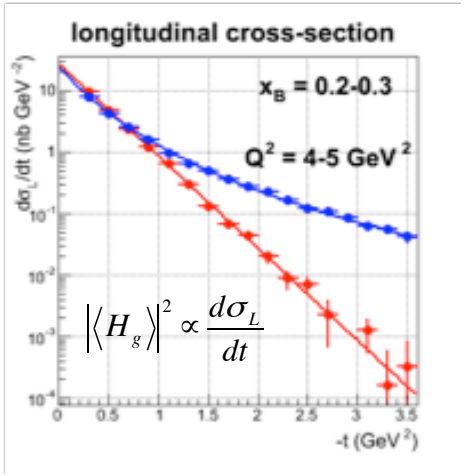
First measurement of J/ψ production near threshold

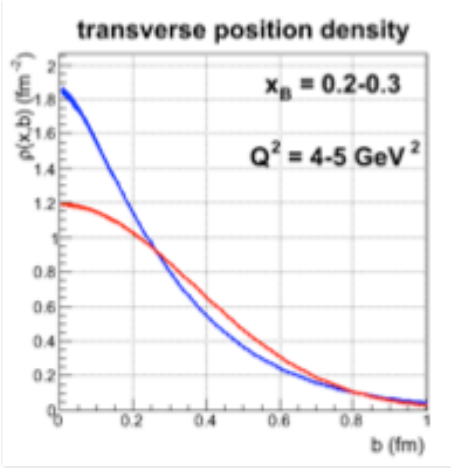
- Establish reaction mechanism
- Access to gluonic structure of the nucleon

E12-12-007 Exclusive Phi Meson Electroproduction with CLAS12

P. Stoler
C. Weiss
F. X. Girod
M. Guidal
V. Kubarovsky







Physics objectives

- Quantify approach to small-size regime in exclusive phi production at $Q^2 > 1$ GeV^2
- Extract nucleon's **gluonic transverse size** in valence region
- Explore signatures of possible intrinsic s-sbar near threshold

Impact and significance

- Unique access to gluons in JLab12 kinematics
- Complements studies of quark transverse distributions with elastic FFs & GPDs
- Results can be directly interpreted & connected with high-energy data
- Growing interest in gluonic structure & imaging with future EIC

Observables and analysis

- Differential cross section dσ/dt: Q^2 and W dependence for reaction mechanism, t-dependence for gluonic size — insensitive to absolute normalization
- L/T ratio from φ -> KK decay — simple, well established technique
- Possible to check φ reconstruction using $K_L K_S$ mode

- **Simple final state, analysis well understood, multiple cross-checks**
- **Immediate physics impact, no global analysis required**

Possible RG Schedule (straw man)

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All Run Groups	**1036**[#)]	30	15	95	105	105	105	105	456
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CLAS12 Comm			3 15						0
RG-A + RG-K (proton)	239*		10	20/15 25		35	20		114*
RG-B (deuteron)	90*				40				50*
RG-F (BoNuS)	42*				21				21
RG-C (NH_3)	120				35	25			60
RG-C-b (ND_3)	65					35			30
RG-E (Hadr.)	60						35		25
RG-H (Transv. Target)	110*						40	20	50
RG-D (CT)	60							40	20
RG-G (LiD)	55							35	20

#) incl. RG-H

RUN Group A Beam Time Request

1) In addition to the 20 days for the commissioning experiment, **high luminosity running of 60 days** is needed for 4 experiments (E12-06-108, E12-06-119, E12-11-005, E12-12-001). Experiment **E12-11-005 requires lower luminosity operation for 39 days**. Experiment E12-12-001 declared that the 80 days plus the 39 days addition low luminosity days are equivalent to the total of 100 days they had requested.

2) E12-12-001 received approval for **additional 20 days of running <u>at reversed Torus polarity</u>**.

The listed RG-A time of 139 days will thus serve all PAC-approved experiments with a total of 559 days of individually approved beam times. (This number does not include the run group experiments, which account for an additional 300 days if run independently.)

3) **Experiment E12-11-005 part of RG-A requires the Forwards Tagger (FT)** that allows for electron scattering at very low Q^2 (10^{-2} -10^{-1} GeV^2), which provides a high photon flux and a high degree of linear polarization, complementary to the capabilities of Hall D. The FT detector systems will require an independent Experimental Readiness Review (ERR) prior to installation and operation as part of CLAS12.

RUN Group A 2017

- KPP run has been a success indeed because it gathered people to focus on this briliant achievement.

- The same effort has to be repeated now and RGA is on the first line, starting with the engineering run.

- With the hopeful delivery of the Solenoid and the full Central Detector, there will be some added difficulties but we will have better tracking..

- C4F10 issue …

The obvious main steps being :

1. Alignment : how do we go from perfect geometry to reality. Need persons in charge (probably for each detector) and procedures and documentation.
2. Cosmic runs during October will be a good opportunity to debug the systems.
3. Calibration: define calibration persons in charge for each detector subsystem.
4. Reconstruction: Proof of principle with simulated data. Seems in good shape
5. Analysis: from reconstructed data to the physics results. Proof of principle with simulated data. Again, need one (or more) person in charge. Is the software ready and available?

6. Etc…

- Use the ACE Committee to transmit our recommendations.