JLab Experiments E12-09-017, E12-09-011, E12-09-002

First-Year of Hall C experiments towards a complete commissioning of the SHMS for precision experiments

Spokespersons: P. Bosted, D. Dutta, R. Ent, D. Gaskell, K. Hafidi, T. Horn, G. Huber, E. Kinney, P. Markowitz, H. Mkrtchyan

Hall C with its heavily-shielded detector setup in a highly-focusing magnetic spectrometer with large momentum reach will be the optimal Hall for certain classes of deep exclusive and semi-inclusive measurements, and in particular those requiring high quality L/T separations. The early running group in Hall C consists of three experiments whose common feature is the tagging of the active quark. These three experiments together will accomplish

- Detailed commissioning of all particle identification detectors, including the dedicated equipment for kaon identification (the SHMS aerogel detector).
- Commissioning of coincidence-type experiments with charged pions and kaons, and broad understanding of detector and tracking efficiencies.
- Understanding of the spectrometers at a systematic level required for Hall C's science program of precision L/T separation and cross section experiments.
- Operational experience of the HMS-SHMS towards their smallest design angles.

A central requirement for two of these three early experiments is the availability of high luminosity and small angles down to 5.5 degrees. The small angle capability is an essential feature of the SHMS and is listed in the SHMS design report and on the Jefferson Lab web pages. The magnets were designed to reach this angle as published in IEEE Transactions on Applied Superconductivity Vol. 19, Issue 3 (P. Brindza et al.). In the described experiments, the run plan would start with SHMS angles larger than 10 degrees. About halfway through the experiments an initial worst-case SHMS momentum/angle combination of 7.1 GeV/c at 7.8^o would be reached. Towards the end the experiments worst-case combinations of 7.1 GeV/c at 6.1^o and 8.3 GeV/c at 7.6^o are envisioned. This should greatly facilitate a slow gain of small-angle SHMS operational experience.

Another requirement for all three experiments is the availability of kaon-proton separation. To take full advantage of the existing SHMS standard detector configuration without compromising its performance, the SHMS aerogel Cherenkov detector was constructed. It features four aerogel refractive indices (1.03, 1.02, 1.015, 1.011) covering a kaon momentum range 3-7 GeV/c. The higher index aerogels have been previously used at MIT/Bates while the two lower index aerogels are new. The detector will be installed in the SHMS by the end of 2015 and remain installed there. An early commissioning period of the kaon aerogel detector, of roughly a shift, would be extremely helpful, and provide sufficient data to analyze the overall performance of the detector in beam and its impact on other detectors in the SHMS. Having this information in hand prior to the entire sequence of experiments requiring kaon identification would allow for more efficient preparations and execution of these experiments. To commission more than one index would have to take into account the time required to change an aerogel tray (estimated at 4-8 hours).

In 2012, the three experiments were asked by Hall C to prepare a global run plan to prioritize various science goals of the semi-inclusive DIS experiments (E12-09-017 and E12-09-002) with the deep exclusive L/T separation experiment (E12-09-011). This followed the consensus reached at the Hall C users meeting preparing for early detector and spectrometer commissioning experiments that to move towards an expedient L/T separation science program in Hall C was a priority. Based on this, the three experiments have worked out a global run plan with phases ordered in priorities.

Roughly, this run plan would be like:

- E12-09-017, 15 PAC days at 2.2 GeV/pass – 5 pass (11 GeV)
- E12-09-017, 7 PAC days at 2.2 GeV/pass – 4 pass (8.8 GeV)
- E12-09-002, 10 PAC days at 2.2 GeV/pass – 5 pass (11 GeV)
- E12-09-011, 16.5 PAC days at 2.2 GeV/pass – 3, 4 and 5 passes
- E12-09-011, 17.5 PAC days at 1.85 GeV/pass – 2, 3, 4 and 5passes
- E12-09-011, 6 PAC days at 1.65 GeV/pass – 3 and 5 passes
- E12-09-002, 12 PAC days at 2.2 GeV/pass – 5 pass
- E12-09-017, 10 PAC days at 2.2 GeV/pass – 5 pass

Note that these last two entries have not been priority-ordered as of yet.

We request commissioning time (8-24 h) adjacent to the detector commissioning period to start the commissioning of the kaon aerogel detector. We also request some dedicated time early on to start commissioning the small-angle (below 10 degrees) capabilities of the SHMS.

We note that – assuming the kaon aerogel detector gets folded into the initial Hall C@12 GeV experiment readiness review – these experiments would solely utilize what would likely become considered "Hall C base equipment". Part of our scheduling request is such that the requirements of these experiments can be folded into this process, and commissioning time can be considered for kaon aerogel detector commissioning and SHMS small-angle operation.

Our complete scheduling request amounts to 32 + 22 + 40 = 94 PAC days, but we have prioritized the run plan in order such that main science goals of the experiments could be accomplished in roughly and equivalent of 74 PAC days. We note that running these three experiments together addresses both the desire of the PAC that "The PAC strongly recommends that these (basic SIDIS cross section) measurements occur in the early years of 12 GeV operation", and the need – with the first and simplest L/T exclusive kaon electroproduction measurements completed – to fully commission the Hall C spectrometer pair to schedule and deliver its highest science priority experiments.

RADIATION BUDGET FORM

PAGE NUM/REV 1/-

Fill in blanks or (preferably) provide in tab-separated or Excel/WKS format.

Hall (circle one): A B C

experiment num.: E12-09-002 E12-09-011 E12-09-017

drawing num. supplied: ______________

name of liaison: Steve Wood

run hours (100% effect.)	days*	21.5	24	3.5	5	2.5	0.5	0.5	4.5	1.5	3.2	6.8	5.4	0.5	0.3	0.7	0.6		0.0
setup number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
beam energy	GeV	11	11	11	8.8	8.8	8.8	6.6	3.8	5.6	7.4	9.3	8.2	3.8	7.4	9.3	8.2		
beam current	uA(CW)	70	50	40	70	50	40	70	70	70	70	70	70	40	40	40	40		mean
polarization	%	60	60	60	60	60	60												
exp/target ID number																			
exp't target material (1)		LH2	LD2	Al	LH2	LD2	Al	LH2	LH2	LH2	LH2	LH2	LH2	Al	Al	Al	Al		
exp't target thickness (1)	mg/cm2	710	1020	536	710	1620	536	710	710	710	710	710	710	536	536	536	536		
exp't target material (2)																			
exp't target thickness (2)	mg/cm2																		
cryo tgt window material		Al	Al		Al	Al		Al	Al	Al	Al	Al							
cryo tgt window thkns	mg/cm2	137	137		137	137		137	137	137	137	137							
radiator material																			
radiator thickness	mg/cm2																		
dist. radiator to pivot*	m																		
exit window material*																			
exit window thickness*	mg/cm2																		
critical dumpline radius*	cm																		
crit. d'pline dist. to pivot*	m																		
dumpline material*																			
dumpline length*	m																		

*ONLY PROVIDED IF NONSTANDARD SETUP.

FYI													OTHER MATERIALS IF USED						
material		D	C	H	Cu	Ti	He gas	Fe	Au	Be	O	Al							
Xo	g/cm2	126.2	43.4	63.1	12.9	16.2	90.7	13.9	6.3	65.8	34.7	24.2							
density	g/cm3	0.162	2.3	0.071	8.93	4.50	1.78E-04	7.87	19.30	1.85									

date form issued: **authors:**

*Day = 24 hours of beam on target. Include fractional days, if appropriate.

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E12-09-002

Charge Symmetry Violating Quark Distributions via Precise Measurement of π^+/π^- Ratios in Semi-inclusive Deep Inelastic Scattering.

Spokespersons: D. Dutta, D, Gaskell and K. Hafidi (contact person)

Principles of symmetry play a vital role in physics, they lead to conservation laws, help determine the allowable laws of nature and serve as guiding principles in search of unification of the laws of physics. The breaking of these symmetries are even more consequential and lead to the observed structure of the Universe. Charge symmetry is one such symmetry principle, under this symmetry, if one were to convert the up quarks in a proton into down quarks (the proton has two up quarks and a down quark) and the down quarks into up, thereby turning the proton into a neutrons (two down quarks and an up quark), the interaction between the quarks remains unchanged. At the quark level charge symmetry is broken because of the significant difference between the mass of up and down quarks. But, the symmetry breaking at the quark level is hidden in nuclei (the mass of the proton and neutron is almost equal). In fact charge symmetry has been routinely assumed to hold for distributions of quarks in protons and neutrons. Describing exactly how this comes about in terms of the accepted theory of the strong force (the force that holds atomic nuclei together), is an excellent test of the theory. But, before we can start to describe how the charge symmetry breaking at the quark level gets hidden in nuclei, we must know exactly how well charge symmetry is respected for quarks inside protons and neutrons. However, charge symmetry has never been rigorously tested, and it has been shown that the uncertainty in the existing experimental data allows for a significant violation of charge symmetry.

We have designed a new experiment that will scatter electrons from a deuterium target (the deuterium nucleus consists of a proton and a neutron bound together) and simultaneously detect the scattered electron and pions that are knocked out of the protons and neutrons. The existing HMS and new SHMS spectrometers in experimental Hall C will be used for this high precision experiment. Detecting pions simultaneously with the scattered electrons tags the type of quark which was struck inside the target nucleus. When a positive pion is detected it implies an up quark was struck while a negative pion indicates that a down quark was struck. The experiment will perform a series of precision measurements alternating between detecting positive and negative pions. These measurements will be used to form a particular ratio of positive to negative pions detected, the exact value of which is very sensitive to the amount of charge symmetry breaking. Thus, this experiment will be the first rigorous measurement of the amount of charge symmetry breaking in the quark distributions inside protons and neutrons. The experiment will allow detailed checks on the theory of the strong force and may also help resolve a long-standing anomalous measurement from neutrino scattering experiments.

JLab Experiments E12-09-011

Studies of the L/T Separated Kaon Electroproduction Cross Sections from 5-11 GeV

Spokespersons: T. Horn, G. Huber, P. Markowitz

The simplest strongly bound quark-gluon systems in nature are the two lightest quark-antiquark pairs, pions and kaons, and the two lightest three-quark systems, protons and neutrons - these also provide the building blocks for the atomic nuclei at the core of the atom. Gaining a quantitative description of the nature of these systems, including a revealing of their inner structure and an understanding of the dynamics that bind them, is thus of great importance for our understanding of the fundamental structure of matter. This experiment is aimed to confirm the potential of kaon measurements both for studies of the kaon structure itself and of the 3D structure of the proton, in terms of spatial imaging (tomography). In particular, **E12-09-011** will probe if the measurements to map the spatial extension of the charged pion can be extended to those of the charged kaon, and if kaons can be utilized to enable 3D spatial tomography of strange quarks.

The **E12-09-011** experiment is an exclusive measurement of the L/T separated kaon electroproduction cross section important for understanding the role of strangeness in GPD studies and the kaon form factor. It will for the first time make precision measurements of the L/T separated kaon electroproduction cross sections as a function of Q^2 above the resonance region. These data will provide information about the onset of the Q^2 evolution in kaon production. A direct comparison of the scaling properties of the π^+ and K^+ separated cross sections would provide an important tool for the study of the onset of factorization in the transition from the hadronic to the partonic regime, and provide a possibility to study effects related to SU(3). The L/T separated cross sections at low **–t** can further provide constraints of the largely unknown kaon form factor.

JLab Experiments E12-09-017

Transverse Momentum Dependence of Semi-Inclusive Pion and Kaon Production

Spokespersons: P. Bosted, R. Ent, H. Mkrtchyan, E. Kinney

The 21st century holds great promise for reaching a new era for unlocking the mysteries of the structure of the atomic nucleus and the nucleons inside it governed by the theory of strong interactions (QCD). The experimental program at the upgraded 12 GeV Jefferson Laboratory plays an important role in this quest exploring the dynamical basis of the structure of hadrons and nuclei in terms of the fundamental quarks and gluons. This experiment is aimed to confirm the potential for studies of the 3D structure of the proton, in terms of momentum imaging (tomography). **E12-09-017** will provide precise measurements of the probabilities to produce charged pions and kaons following electron-quark scattering, and compare this with our theoretical understanding of this process - this will be critical in validating the entire 12-GeV science program of 3D momentum tomography.

The **E12-09-017** experiment plans to make precise measurements of the semi-inclusive DIS (SIDIS) cross sections for π^+ and π^- at low transverse momentum $\mathbf{p}_T$ from hydrogen and deuterium targets. The cross section measurements will provide a strong test of the theoretical understanding of SIDIS in terms of parton distributions convoluted with fragmentation functions. This will play a critical role in establishing the entire SIDIS program at a 12-GeV JLab of studying the partonic structure of the nucleon. The data will further be analyzed in order to extract measures of the mean transverse momentum of up and down quarks in the nucleon. Charged-kaon data will be simultaneously collected that provide insight into the same issues of factorization as planned for pions. The use of longitudinally polarized beam will simultaneously allow measurements of the azimuthal single beam spin asymmetries at low $\mathbf{p}_T$.