NPS Physics Meeting
12 Dec 2012


NPS=Neutral Particle Spectrometer
[or, e.g., National Park Service…]

- **Requirements Document Draft**
  - **Review of Experiment Requirements**
  - **Progress on questions from Orsay WS related to kinematics, detector, etc.**
- **Strategy for PAC submission and equipment funding**
  - **Review of detector characteristics**
- **Organization of next formal workshop on Thur. Jan 24**

Orsay Workshop:
https://indico.in2p3.fr/conferenceTimeTable.py?confId=7052#all.detailed

Requirements Document

Goal: summarize our entire program to be carried out with neutral particle spectrometer for PAC/JLab management **[even if we only submit part of it at next PAC]**

Possible overall structure:

- Executive summary
- Introduction
- Individual Measurements and requirements
- Conceptual Design considerations
- Description of the device

Possible structure for individual sections:

- Brief description of experiment
- Instrumentation Requirements
- Special Requirements

maybe?

D. Exclusive Neutral Pion Production: relative contribution of σ_L and σ_T

Recent experimental results on pion electroproduction provided clear evidence for strong contributions from transversally polarized virtual photons. This observation is in sharp contrast to the handbag factorization which tells us that for asymptotically large photon virtualities, Q, longitudinally polarized photons dominate. According to the handbag approach the amplitudes for transverse photons are suppressed $\sim 1/Q$ as compared to those from longitudinal photons. The experimental evidence for strong transverse virtual photon transitions comes from the HERMES π^+ data [16] on the sin ϕ_s harmonics measured with a transversally polarized target and from the CLAS measurement [17] of the π^0 cross sections which reveals a transverse-transverse interference cross section that amounts to a substantial fraction of the unseparated cross section.

It has been argued in [18, 19] that, within the handbag approach, the amplitudes for transitions are under control of transversity GPDs, in particular of H_T and $\bar{E}_T$=$2\tilde{H}_T + E_T$. In order to evaluate the amplitudes the transversity GPDs are modeled with the help of the double-distribution ansatz. The pertinent parameters are fixed by fitting the HERMES data on π^+ electroproduction and by lattice QCD results [20]. Estimates of various observables using these GPDs are in fair agreement with experiment. One should bear in mind that these estimates have uncertainties of about a factor of two. In order to determine the transversity GPDs more precise data on π^0 (and on other pseudoscalar meson) electroproduction at larger values of Q^2 and W as available at Jlab 6, are needed. A particularly clean probe of large transversity effects in pion electroproduction is the measurement of the ratio σ_L/σ_T as a function of Q^2. The standard handbag approach predicts $\sigma_L >> \sigma_T$ while strong transversity effects would lead to $\sigma_L < \sigma_T$. Predictions [4] for σ_L/σ_T are shown in Fig. 1.

Exclusive π^0 electroproduction with L/T separation could confirm the large contribution from transversely polarized photons to this process and may subsequently allow for a detailed investigation of transversity GPDs [21].

General Instrumentation Requirements:

- Photon detector with good coordinate and energy resolutions and large solid angle
- Sweeping magnet (0.3 Tm appropriate) between target and photon arm
- Magnetic spectrometer for second arm: HMS

Special Requirements:

- For 60% acceptance require a 25 msr neutral particle detector at 4m from the target. This corresponds to an active area of 74cm x 64cm
- Need photon detection system on HMS side covering angles between 10 and 23 degrees
- Require non-standard beam energies for sufficient $\Delta\epsilon$ separation in L/T

Requirements Document

Goal: summarize our entire program to be carried out with neutral particle spectrometer for PAC/JLab management **[even if we only submit part of it at next PAC]**

Editing:

- Executive summary
- Introduction (P. Kroll, M. Vanderhaeghen,…?)
- Individual Measurements and requirements
  - DVCS unpolarized (Charles, Carlos, …?)
  - DVCS polarized (Charles, Carlos, …?)
  - WACS (Bogdan, Donal…?)
  - Exclusive π0 (TH, …?)
  - SIDIS π0 (Hamlet, Rolf,…?)
- Conceptual Design considerations
- Description of the device

Timeline:

- January 24, 2013: individual sections
- February 2013: other sections
- March 2013: discussion and editing of preliminary draft
- April 2013: discussion and editing of full draft
- May 2013: final document
- PAC40: June 17-21, 2013

Requirements Review

Parameter	DVCS unpolarized	DVCS polarized	WACS	Exclusive π0	SIDIS π0
Coordinate Resolution				2-3mm	2-3mm
Energy Resolution					
Sweeping magnet	0.3 Tm	0.3Tm	0.3Tm	0.3Tm	0.3Tm
Second arm spectrometer	HMS	HMS	HMS	HMS	HMS
Photon angles	12.4-23.0		50-60	10.1-23.4	16.3-19.2
Acceptance				60%/25msr	10-60%/25
Currents	2.5-25 μA	60(?)μA	40μA	1-2 μA*	1-2 μA*
Targets	LH2	30cm ^{3}He	15cm LH2	10cm LH2	10cm LH2
Special req.			8% Cu	Non-standard energies for $\Delta\varepsilon$	LD2

*preferably higher, pending info on background

DVCS Unpolarized

Physics motivation: energy dependence to isolate twist-2/twist-3 effects

- One kinematic setting from table has HMS momentum 7.7 GeV/c, which exceeds HMS nominal operation of 7.3 GeV/c
  - ***One possible alternative (that also works for π0 exclusive):***
    - Increase to Q^2=3.5 GeV^2 and keep x=0.50
    - Another option: decrease x=0.45 and keep Q^2=3.10 GeV^2

W	Q^2	t_{min}	x_B	E_e	E_e'	θ_e	ε	$P_{\pi 0}$	$\theta_{\pi 0}$
2.09	**3.50**	**0.378**	**0.50**	10.9/6.6	7.17/2.87	12.2/24.8	0.90/0.67	3.53	21.2/16.8
2.09	**3.10**	**0.317**	**0.47**	10.9/6.6					

DVCS Polarized

Physics motivation: separate GPDs on the x=xi line

- Concern: secondary background from target when using polarized target together with sensitive photon detector

WACS

Physics motivation: validate GPD formalism at large t

- Kinematics suggest that one cannot run this experiment together with mesons and DVCS: radiator requirement is not compatible. Fits with the general facility though.
- Can one run at 40 mA for the full experiment (with a 6-8% radiator)?

Exclusive π^0

Physics motivation: relative contribution of σ_L and σ_T

- Acceptance is 60% with PbWO4 geometry. Can one do this experiment with the smaller PbF2 detector?

- Maximum possible currents at larger angles?

- Would some of the kinematic settings from the DVCS kinematics table, e.g., higher Q^2 work for this experiment?

Exclusive π^0 combine with DVCS

π^0 photon angles between 10.1 and 23.4 degrees

Sufficient $\Delta\varepsilon$ separation requires lower energies

W	Q^2	t_{min}	x_B	E_e	E_e'	θ_e	ε	$P_{\pi 0}$	$\theta_{\pi 0}$
2.49	**3.00**	**0.165**	**0.36**	10.9/6.6	6.46/2.16	11.9/26.5	0.86/0.53	4.35	16.2/11.7
2.09	**3.50**	**0.378**	**0.50**	10.9/6.6	7.17/2.87	12.2/24.8	0.90/0.67	3.53	21.2/16.8
2.38	**4.80**	**0.392**	**0.50**	10.9/6.6	5.79/1.49	15.9/41.0	0.80/0.36	4.90	16.51/10.1
2.53	*5.50*	0.398	0.50	10.9/8.2	5.04/2.34	18.2/31.1	0.73/0.47	5.65	14.44/11.02
1.94	3.50	0.486	0.55	10.9/6.6	7.50/3.20	11.88/23.50	0.91/0.73	3.14	23.43/19.17
2.40	3.50	0.243	0.42	10.9/6.6	6.44/2.14	12.83/28.86	0.86/0.53	4.34	17.16/12.29

DVCS Kinematics Table Hall A E12-06-114

		Hall A E12-06-114			Hall C complement at fixed (Q^2, x_{Bj})								
Q^2	x_{Bj}	k	k'	θ_q	k	k'	θ_e	θ_q	k	k'	θ_e	θ_q	Days HallC
3.00	0.36	6.60	2.16	11.7	8.80	4.36	16.08	14.7	11.00	6.56	11.70	16.2	6
4.00	0.36	8.80	2.88	10.3					11.00	5.08	15.38	12.4	3
4.55	0.36	11.00	4.26	10.7									
3.10	0.50	6.60	3.30	19.0	8.80	5.50	14.55	21.6	11.00	7.70	10.98	23.0	10
4.80	0.50	8.80	3.68	14.5					11.00	5.88	15.65	16.6	4
6.30	0.50	11.00	4.28	12.4									
7.20	0.50	11.00	3.32	10.2									
5.10	0.60	8.80	4.27	17.8					11.00	6.47	15.38	19.8	13
6.00	0.60	8.80	3.47	14.8					11.00	5.67	17.84	17.2	16
7.70	0.60	11.00	4.16	13.0									
9.00	0.60	11.00	3.00	10.2									
		Total Days		88									52

At 2 μA initial LH2 time estimate: 1138 days (47 days)

Opportunity to combine 288 hours at 10.9 GeV with DVCS

Semi-Inclusive π^0

Physics motivation: relative contribution of σ_L and σ_T

- Acceptance is 10% at z=0.4 with PbWO4 geometry and seems to require larger geometry than existing PbF2 offers. Can anything be done with PbF2 at smaller distance?

- Maximum possible currents at larger angles?

- Would some of the kinematic settings from the DVCS/exclusive π0 kinematics table work for this experiment?

Exclusive and SIDIS π^0 Kinematics

Small forward angles for SIDIS

W	Q^2	t_{min}	x_B	E_e	E_e'	θ_e	ε	$P_{\pi 0}$	$\theta_{\pi 0}$
2.98	2.00	0.043	0.20	6.6/8.2/10.8	1.3,2.8,5.4	28.3,16.96,10.63	0.34,0.60,0.79	5.5,5.3,5.3	6.3,8.6,10.5
2.81	3.00	0.108	0.30	6.6/8.8/10.9	1.2,3.4,5.5	34.8,18.2,12.85	0.33,0.65,0.79	5.6,5.3,5.3	7.4,11.0,12.7
2.62	4.00	0.218	0.40	8.2,10.9	2.8,5.5	24.1,14.85	0.58,0.78	5.2,5.2	11.7,14.4
2.01	3.50	0.378	0.50	6.6,10.9	3.0,7.1	23.7,12.2	0.70,0.90	3.5,3.5	17.4,21.2
2.21	4.00	0.384	0.50	8.2,10.9	3.9,6.6	20.5,13.6	0.73,0.86	4.1,4.1	16.8,19.2
2.45	5.10	0.395	0.50	8.2,10.9	2.7,5.4	27.8,16.9	0.55,0.77	5.2,5.2	12.4,15.6
1.90	2.45	0.312	0.47	4.4,8.8	1.6,6.0	34.6,12.4	0.56,0.91	2.6,2.6	16.5,23.9
2.00	3.80	0.491	0.55	6.6,10.9	2.8,7.2	26.0,12.7	0.67,0.90	3.4,3.4	17.5,22.2

Summary

Common features of the experiments:

1) Good photon detector: coordinate and energy resolutions, large solid angle
   → PbWO4 detector with good position resolution helps
   → solid angle similar as for 6-GeV experiments, well matched to proton arm

2) Magnet between the target and the photon arm
   → 0.3 Tm appropriate

3) Magnetic spectrometer for the second arm
   → HMS appropriate

Special considerations:

1) DVCS unpolarized: pre-shower benefits? High currents
2) DVCS polarized: secondary backgrounds from target
3) WACS: Radiator and Luminosity: 40 μA x {8% Cu + 15 cm LH2} , large scattering angle of the photon up to 50-60 degrees
4) Mesons: Acceptance, second lower energy for $\Delta\varepsilon$ in L/T
5) ….

Neutral Particle Detector: Options

Material	PbWO4	PbF2
Dimensions	64cm x 74cm	36cm x 33cm
Crystal size	2.05cm x 2.05cm	3.0cm x 3.0cm
Number crystals	1116	132
Distance from target	4 m	1.1 m
Position resolution	2-3 mm	2 mm
Resolution/crystal	5 mrad	27 mrad
Angular resolution	0.5-0.75 mrad	
Energy resolution	1.5-2.5%	2.4 %

Components of the detector

- Calorimeter blocks (PbWO4 or PbF2)
- Small-diameter PMTs with new active HV base (PbWO4)
- Temperature controlled frame (PbWO4)
- Sweeping magnet (PbWO4)
- Digitizing electronics (PbWO4 and PbF2)
  - Essentially dead-time-less (PbWO4)

Neutral Pion Detection: Geometric Acceptance

z	E_{π^0} (GeV)	acceptance (%)
0.40	2.132	9.43 ± 0.03
0.50	2.665	20.23 ± 0.04
0.60	3.198	29.92 ± 0.05
0.70	3.731	38.47 ± 0.05
0.80	4.264	45.91 ± 0.05
0.90	4.797	52.42 ± 0.05
1.00	5.330	58.26 ± 0.05

SIDIS

Exclusive

Geometric acceptance of π^0 detection in a calorimeter with 58 x 70 cm2 active area at 4 m from the target.

Acceptance is quoted as relative to the ~25msr opening angle

Neutral Particle Detector: Questions

General questions:

- What are the technical requirements driving either the PbWO4 or PbF2 choice? Linearity and background?
- Do we want a standalone calorimeter accommodating all measurements? For PbF2 this would require purchasing additional crystals for 25 msr device (driven by meson experiments).
- What are highest possible currents at different calorimeter angles?

Specific questions

- Does the PbF2 calorimeter fit in Hall C with sweeping magnet and also at lower angles?
- Can entire exclusive program be done with available PbF2 crystals at shorter distance?
- Pre-shower beneficial for DVCS, e.g., transverse resolution?
- Funding strategy? Apply in 2014 or 2015 for NSF/MRI?
- Funding options: NSF/MRI, European Sources(PUF, Chateaubriand, ...),…