





# **Status of Hall B**

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CLAS Collaboration Meeting June 18 -21, 2019

- Science questions
- Overview, NIM papers, publication, talks
- Update on PrimEx, PRad, CLAS, HPS
- CLAS12 performance
- Physics Runs RGA, RGK, RGB
- Schedule
- Summary/Outlook





### **Critical Science Questions**

- How do we reveal the quark structure of nucleons, N\* excited states, and forces at the sub-femto-meter scale?
- What does the quark/gluon orbital angular momentum contribute to the proton's spin?
- What is the role of glue in the spectroscopy of light mesons and baryons?
- What is the nature of short range forces acting in nuclei?
- Can we discover evidence for physics beyond the standard model of particle physics?



### Hall B science program is decisive in addressing these questions





### Hall B Overview

- 125 CLAS members have registered for the collaboration meeting
- CLAS12 first physics runs: RG-A (13 proposals, 139 PAC days), RG-K (3 proposals, 100 PAC days), RG-B (7 proposals, 90 PAC days)
- Continued flow of results from Hall B (CLAS+PRAD+HPS+PRIMEX..)
  - > 220 physics papers in peer reviewed journals (> 10,000 citations)
  - 3 papers in Nature (+1 submitted), 1 paper in Science
  - ~2,500 conference talks (~1,600 invited)
- Specialized Hall B experiments

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- PRIMEX experiment PRIMEX II  $\pi^0$  L.T. results in preparation , Compton scattering with NLO corrections.
- PRAD experiment results submitted to Nature for publication
- Heavy Photon Search Analysis of 2016 data ongoing, HPS 2019 run has started.





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# **NIM Articles**

### Status of CLAS12 NIM Papers – 6/13/19

Subsystem	Lead	% Comp	Pages	Reviewer	Review	Status Update
SVT	Gotra/Elouadrhiri	100	18	Carman	Rev. #1 done	2 <sup>nd</sup> draft complete
MVT	Bossu/Defurne	50	10			Need update
CTOF	Carman	100	33	Gothe	Rev. #1 about to start	
CND	Niccolai	75	10	Carman	Rev. #1 done	Working on 2 <sup>nd</sup> draft
HTCC	Sharabian	75	10		Internal review done	Working on figures/edits
DC	Mestayer	50	20			Writing; needs figure work
LTCC	Ungaro	75	17	Carman	Rev. #1 done	2 <sup>nd</sup> draft in progress
RICH	Rossi/Contalbrigo	50	8			Need update
FTOF	Carman	100	27	Gothe	Rev. #1 about to start	
ECAL	Smith/Stepanyan	50	9			Making progress
FT	Battaglieri/De Vita	50	13			Making progress
Beamline	Stepanyan/Raue	100	15	Raue	Rev. #1 done	Need to work on figures
DAQ	Boyarinov	100	17	Carman	Rev. #1 done	Marked up copy returned
Trigger	Kubarovsky	100	14	Carman	Rev. #1 about to start	Draft almost complete
Sim	Ungaro	100	28	several	Rev. #1 in progress	Need subsystem feedback
Reconstruct	Ziegler/De Vita	0	0			
Magnets	Fair/Kashy	100	33	Carman	Rev. #1 in progress	
Overview	Burkert/Elouadrhiri	90	27			
OVERALL		75.8%	309		Key: Updated	since last meeting



## CLAS12

# **NIM Timeline**

Milestone	Date
Kickoff meeting	8/2/2018
Detailed outline of each article	9/6/2018
Detailed outline of the complete document on github; list of drawings needed	10/4/2018
First draft	4/18/2019
Initial draft reviews	4/2019 - 6/2019
Complete/mature draft with preliminary data	7/15/2019
Draft reviews	7/2019 – 8/2019
Final draft (submitted for internal review)	9/1/2019
Complete internal reviews	10/15/2019
Submission of papers to NIM complete	11/30/2019

The editorial board approved at unanimity the CLAS12 Special Issue proposal. We are thrilled to publish it in NIMA journal.

Repository: https://github.com/JeffersonLab/clas12Nim





# **Refereed Physics Publications**



	Spectroscopy	Hard scattering	Nuclear	ALL	<u> </u>
2000	-	1	1	2	
2001	2	3	-	5	
2002	3	-	1	4	publ
2003	7	4	1	12	subm
2004	3	3	4	10	Subin
2005	7	3	2	12	
2006	8	4	3	15	
2007	7	2	3	12	
2008	4	6	2	12	
2009	8	7	4	19	
2010	4	2	4	10	
2011	3	1	4	8	
2012	6	3	2	11	
2013	8	6	2	16	
2014	5	6	1	12	
2015	4	5	3	12	
2016	7			7	
2017	12	7	1	20	
2018	10	6	2	18	
2019	<mark>3</mark> +1	<b>1</b> + 2	<b>2</b> +2	<mark>6</mark> + 5	
SUM	<b>111</b> + 1	<b>70</b> + 2	<b>41</b> +2	<b>222</b> +5	updated 6/16/2019



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### **Conference Presentations**







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### **Conference Presentations**

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Source: HPS & PRAD wiki

updated 21 May 2019

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#### **Compton Scattering** Hall B



The cross section of atomic electron Compton scattering  $y + e \rightarrow y' + e'$  measured in the 4.40–5.475 GeV photon beam energy region with < 2% accuracy.

The results are consistent with theoretical predictions that include next- to-leading order radiative corrections.

First high precision test of this elementary QED process at beam energies greater than 0.1 GeV.

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P. Ambrozewicz at al., arXiv:1903.05529

$$\gamma + e^{-} \Longrightarrow \gamma + e^{-}$$

### (Klein-Nishina formula)

$$\frac{d\sigma}{d\Omega} = \frac{r_e^2}{2} \frac{1}{[1+\gamma(1-\cos\theta)]^2} [1+\cos^2\theta + \frac{\gamma^2(1-\cos\theta)^2}{1+\gamma(1-\cos\theta)}]$$





#### PrimEx II Γ**(**π⁰→γγ)

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# **Proton Charge Radius**



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PRad R<sub>p</sub> (current) = 0.831  $\pm$  0.007 (stat.)  $\pm$  0.012 (syst.) fm

### Submitted for publication in Nature

Results show that proton charge size is consistent with muonic hydrogen value (first electron scattering result to agree with muonic hydrogen spectroscopy)



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# **EMC effect and SRC**





EMC data can be explained by a universal modification of the structure of nucleons in neutron–proton SRC pairs. This implies that in heavier nuclei with many more neutrons than protons, each proton is more likely than each neutron to belong to an SRC pair and hence to have distorted quark structure.

B. Schmookler et al. (CLAS), Nature 566 (2019) no.7744, 354-358





### Beam-target asymmetries $\tilde{\gamma} p \rightarrow \tilde{p}$ pω







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P. Roy et al. (CLAS), Phys.Rev.Lett. 122 (2019) 162301



PWA need newly discovered nucleon resonances from CLAS and other data: N(1880)1/2<sup>+</sup>, N(1895)1/2<sup>-</sup>, N(1875)3/2<sup>-</sup>, N(2120)3/2-. Also strong evidence is found for N(2000)5/2<sup>+</sup>.(previously seen in PWA of CLAS single channel  $\omega$  data analysis.)





# Hall B Beamline (for HPS run) Hall B



### **Current Status:**

- Hall-B ready at 5pm on Friday 6/14 to accept beam
- First beam to tagger dump Sunday owl shift Beam to Faraday cup, and through chicanes
- This week develop HPS production quality beam

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• Expect to begin production running at 400nA and 4mu W target







## **Detector**











## Hall B FY'19 Lab agenda items

#### I. <u>Make significant progress in data taking for several run groups</u>

- 1) Complete 40% of RG-A (includes data for 13 individual experiments)
- 2) Complete 15% of RG-K (includes 3 individual experiments) (achieved 12% due to reduced beam)
- 3) Complete 20% of RG-B (includes data for 7 individual proposals)
- 4) Complete 25% of HPS approved beam time. (Started summer run)
- II. In preparation for efficient running of RG A&B complete the heavy gas (C<sub>4</sub>F<sub>10</sub>) recovery system for the low threshold Cherenkov counters (LTCC) (Q2)
- III. Complete preparations for first proof of principle test in the UITF for the HDIce electron beam run. (Q4)
- IV. Prepare two high impact physics analyses for publication. (Q4)

1) Beam spin asymmetries for DVCS  $p(e,e'\gamma p)$  or SIDIS  $p(e,e'\pi^0)X$ . Both processes are related to the 3D imaging program with CLAS12.

2) Meson spectroscopy with exclusive  $p(\gamma_{qr}, \rho^0 p)$  quasi-real photoproduction using the FT for photon tagging.







### **RG-A Production Charge**









# **CLAS12** Run Group A – p(e,e')X, PID

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## **CLAS12** RGA – $p(e,e')X, p(e,e'\pi^+)X$



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# **Run Group K**



	RG-K		Experiment	•	3 experime	ents				
	E12-16-010	A search for hybrid ba	ryons in Hall B with CLAS12	•	Polarized e	lectrons or	liquid-hydrogen targe	>t		
	E12-16-010A	Nucleon resonances in	excl. KY electroproduction	1						
	E12-16-010B	DVCS with CLAS12 at 6	5.6 and 8.8 GeV	· ·	Torus settir	ng: Negativ	es out-bending			
RG	-K	E=7.5GeV	Fall 2018	E	=6.5GeV	****	Nov. – Dec. 2018			
rent [nA]			ſ	Machine down FT-OFF			CHARGE			
beam cur					<b>***</b> ******		$Q^{45mC} = 7\%$ of			
30										
	30. Nov	2. Dec 4. Dec	6. Dec 8. Dec 10. De 8 hours) - gated charge - ur	عد 12. Dec 14. Dec Ingated charge charge colle	16. Dec 18. cted at 75 nA and 50% AB	Dec 20. Dec				

Beam Energy	Beam Current	Targe t	Trigger	Collected Events	COL
7.5 GeV	35 nA	$LH_2$	e in CLAS or (e in FT + 1 Fwd Hadron)	3.5 G	EVE
7.5 GeV	45 nA	$LH_2$	e in CLAS – pre-scaled or (e in FT + 1 Fwd Hadron	4.3 G	15.6
6.5 GeV	60 nA	$LH_2$	e in CLAS	7.8 G	



### **RGK & Electron Scattering & PID CLAS12**





# Status of RG-A & RG-K

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	RG-A: Collected charge of high luminosity runni At L = $10^{35}$ cm <sup>2</sup> s <sup>-1</sup> this corresponds to: 40.1 char Low luminosity for 7 scheduled days: 3.5 charge Total: 40.1 charge days + 9.6 spring = <b>49.7 cha</b>	ng: 220mCb   ge days RG-K: Collected charge: 45.6mCb   days At L = 10 <sup>35</sup> cm <sup>-2</sup> s <sup>-1</sup> this corresponds to: 7.1 Charge days   in terms of ABUs this corresponds to 12.1 PAC days				e days ays				
Proposal	Physics		Contact	Rating	Approved days	ABU days	% ABU	Charge days	% Charge	comment
E12-06-108	Hard exc	clusive electro-production of $\pi^0$ , $\eta$	Kubarovsky	В	80	64	80.2	49.7	62.1	
E12-06-108A	Exclusiv	e N*->KY Studies with CLAS12	Carman	NR	(60)	64	100.	49.7	82.8	
E12-06-108B	Transitio	on Form Factor of the $\eta$ ' Meson with CLAS12	Kunkel	NR	(80)	64	80.2	49.7	62.1	
E12-06-112	Proton's	quark dynamics in SIDIS pion production	Avakian	Α	60	25	42	20	33	1/ <mark>2</mark> LTCC, 1 RICH
E12-06-112A	SIDIS A	productiuon in target fragmentation region	Mirazita	NR	(60)	25	42	20	33	1/ <mark>2</mark> LTCC, 1 RICH
E12-06-112B	Colinear	nucleon structure at twist-3	Pisano	NR	(60)	25	42	20	33	1/2 LTCC, 1 RICH
E12-06-119(a)	Deeply V	/irtual Compton Scattering	Sabatie	Α	80	64	80.2	49.7	62.1	
E12-09-003	Excitatio	on of nucleon resonances at high Q <sup>2</sup>	Gothe	B+	40	64	100	49.7	100.	
E12-11-005	Hadron s	spectroscopy with forward tagger	Battaglieri	A-	119	64	54.0	53.2	44.7	
E12-11-005A	Photopro	oduction of the very strangest baryon	Guo	NR	(120)	64	53.5	49.7	41.4	
E12-12-001	Timelike	Compton Scatt. & J/ψ production in e+e	Nadel-Turonski	A-	120	64	53.5	53.2	41.4	
E12-12-001A	J/ψ Phot	oproduction & study of LHCb pentaquarks	Stepanyan	NR	(120)	64	53.5	49.7	41.4	
E12-12-007	Exclusiv	e $\phi$ meson electroproduction with CLAS12	Girod	B+	60	64	100	49.7	82.8	
RG-A completion					139			43.4	53.5	
E12-16-010	A search	for Hybrid Baryons in Hall B with CLAS12	D'Angelo	A-	100	12.1	12.1	7.1	7.1	
E12-16-010A	Nucleon	Resonances in exc. KY electroproduction	Carman	A-	(100)	12.1	12.1	7.1	7.1	
E12-16-010B	DVCS wi	th CLAS12 at 6.6 and 8.8 GeV	Elouadrhiri	A-	(100)	10.0*	10.0	5.7	5.7	Correction low energy
RG-K completion					100					





# **Run Group B**



+ J/psi photoproduction & SRC

2019 schedule: first part of RG B in Febuary 6th - March 25th 2019, second part in <u>November 1st - December 19th</u> → 44.5 PAC days (1/2 of approved run time)

#### **Statistics for the spring run:**

- 237 « good » production runs + various ancillary runs
- « Production » beam current: 50 nA
- ~9.7 B events at 10.6 GeV, 11.7 B events at 10.2 GeV
- Average beam polarization ~86% (22 Moeller runs)
- PAC days (according to ABUs): 21.8

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- ✓ First round of preliminary calibrations done
- ✓ Pass0 cooking done with COATJAVA 5.9.0
- ✓ New pass0 with COATJAVA 6b.2.0 ongoing







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### CLAS12 RG-B

RG-B: Scheduled for February 8 – March 19. 6 days were taken from RG-A and added to RG-B to compensate for poor machine operation. RG-B collected 21.8 ABU days (= PAC approved beam days. ) Collected charge:

	Physics	Contact	Rating	Days	% complete	comment
E12-07-104	Neutron magnetic form factor	Gilfoyle	A-	30	72.7	
E12-09-007(a)	Study of partonic distributions in SIDIS kaon production	Hafidi	A-	30	36.3	2 LTCC, 1 RICH
E12-09-008	Boer-Mulders asymmetry in K SIDIS w/ H and D targets	Contalbrigo	A-	30	36.3	2 LTCC, 1 RICH
E12-09-008B	Colinear nucleon structure at twist-3	Mirazita	NR	(56)	38.9	
E12-11-003	DVCS on neutron target	Niccolai	Α	90	24.2	
E12-11-003A	In medium structure functions, SRC, and the EMC effect	Hen	NR	(90)	24.2	
E12-003B	J/Psi production on deuterium	llieva pentaquark J/Psi	NR	(80)	5.5 *) 8.3	Suffers from low energy
RG-B completion				21.8	24.2	

\*) Entries are weighted with factor less than 1 to account for reduced beam energy during part of the run.

Updated June16, 2019





### **RGB: CND & BAND**





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# **RGB - nDVCS Analysis**

- Runs 6164, 6215, 6240, 6289, 6310, 6489, COATJAVA 5.9.0
- PID: electron neutron gamma detected (EB)
- Kinematic cuts: Q<sup>2</sup>>1 GeV<sup>2</sup>, p(e)>1 GeV, q(e)>5.5°, p(n)>0.35 GeV
- Preliminary « spectator » and « DVCS » cuts on MM<sup>2</sup>(eng), missing energy, missing momentum, E<sub>g</sub>>2 GeV
- nDVCS+BH simulation: GENEPI + GEMC 4.3.0 + COATJAVA 5.9.0







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### **BONuS12** Detector construction







# **CLAS12** Polarized NH<sub>3</sub>/ND<sub>3</sub> Target





ERR for RG-C June 17, 2019

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Target on track for installation Summer 2020.



## Scheduled Hall B Runs in 2019/20

Schedule	Experiment	Energy (GeV)	Polarization	Days	Total days					
CY 2019										
01/30 - 03/25	RG-B	10.6/10.2	max	45						
03/25 - 04/15	RG-A	10.2	max	20	79					
06/17 - 08/18	HPS	4.55	-	63	63					
11/01 – 12/19	RG-B	10.5 (expect.)	max	48	93					
		CY 2020	0							
01/22 - 01/23	BONUS12	2.2	-	2						
01/24 - 04/10	BONUS12	10.6	-	78	80					
04/11 - 05/05	04/11 – 05/05 Contingency			24						
	Likel	y no beam in ren	nainder of 202	20						





### PAC47 – Proposals/LOI

#### Proposals/LOIs **Physics** Contact <u>Days</u> PR12-19-004 (RGN) Search for phi-N bound state 45 Gao Photoproduction of hadrons E12-11-003C (RGB) Hauenstein E12-07-104A (RGF) Tagged neutron DVCS with BoNuS12 Hattawy Charged current production in Bjorken kinem. Siddikov LOI12-19-001 LOI12-19-005 Next generation Tritium experiments in CLAS12 Hen New beam time requested for Hall B Proposals: 45



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# Summary/Outlook

Continuous flow of results from CLAS being published, PRad results submitted to Nature, PrimEx I (Compton scattering) & PrimEx II finalized.

 CLAS12 completed data taking for initial installments of RG-A & RG-B, and some 12% of RG-K

Production data processing for RG-A in final preparation

9 weeks of HPS running in the summer at 4.5 GeV, Hall B saw first beam on the weekend.

Continue RGB during fall of 2019, and run BoNuS12 in the winter/spring of 2020.













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### **FD** performance & specs



Current (nA)	Parameter	Shift	sigma	specs	Comment
0		-0.083%	0.52%	< 1%	
60	$(P_{rec} - P_{mc})/P_{mc}$	-0.083%	0.67%	< 1%	
120		-0.080%	0.86%	<1%	
0		-0.003°	<b>0.04</b> °	0.06	
60nA	$\Theta_{\rm rec} - \Theta_{\rm mc}$	<b>-0.00</b> 4°	0.05°	0.06	
120nA		-0.002°	<b>0.05</b> °	0.06	
0		-0.020°	0.19°	0.235*)	
60nA	$\Phi_{\rm rec}$ – $\Phi_{\rm mc}$	-0.018°	0.22°	0.235	
120nA		-0.027°	0.25°	0.235	$\checkmark$
0		-0.14mm	3.6mm	N/A	
60nA	$Vz_{rec} - Vz_{mc}$	-0.23mm	4.6mm	N/A	
120nA		+0.04mm	5.6mm	N/A	

- 1) Shifts of mean value seen at all currents, but negligible in size, even at 120nA
- 2) Widths increase with current, most significant for momentum
- \*) < 1 mrad/sinO, track at 15°

N/A z-vertex resolution not spec'd





# **RG Schedule (strawman)**

Run Group	Days	CY2016	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	Rest
All Run Groups	1136 <sup>#)</sup>	30	58	93	42 + 25?	110	110	110	583
HPS	180*	15		35		31		30	70
PRad	15 <b>*</b>	15							0
RG-A	139 <b>*</b>		46	13				50	30*
RG-B (deuteron)	90*			22 <u>23</u>					45*
RG-F (BoNuS)	42*				42 도				0
RG-C (NH <sub>3</sub> ,ND <sub>3</sub> )	185				NO	40	50		95
RG-E (Hadr.)	60	-			or d			30	30
RG-H (Transv Targ)	110*	СЕВА	F Large Acceptance Spectro	meter	rato				110
RG-D (CT)	60				ele		30		30
RG-G (LiD)	55				Acc				55
RG-K (N <sup>*</sup> <sub>G</sub> /Conf.)	100		11			39			50
RG-L (ALERT)	55						30		25
RG-M (e4v, src)	45				25 ?				20



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