

### Jefferson Lab 12 GeV Science Program



QCD Evolution May 12, 2014



### **A Laboratory for Nuclear Science**



Quark Confinement Hadrons from Quarks Theory and Computation





### **12 GeV Upgrade Project**





### **12 GeV Upgrade Project Schedule**



16-month installation May 2012 - Sept 2013

Accelerator commissioning start Oct 2013

Hall A commissioning start Feb 2014

Hall D commissioning start Oct 2014

Halls B & C commissioning start Jan/Feb 2016

Project Completion September 2017

> Re-baseline Approved September 4, 2013





#### **12 GeV Project Highlights**





Hall B











### **Accelerator Commissioning Progress**







### May 7, 2014

Channel 4 2014-05-07 23:41:24

- 5.5 Passes
- 10.5 GeV
- Transported to Hall D Tagger Dumplet
- Completes CD4a Project
   milestone







### Three year plan

Dec 2013 Jefferson Lab Three-Year Schedule										
	Calendar Year			014		201	5	2016		
	Fiscal Year		2014			2015		2016		
CEBAF	Activity Beam	Com	missioning		Çomm.	Physics	Physi	cs Physics		
Hall A	Activity Beam	Const.	Comm.		Comm.	Physics	Physi	cs Physics		
Hall B	Activity Activity Beam	•	CI	.AS12 C	onstru N	ction/Installat Ion-CLAS12 Op	tion s	→ Comm.		
Hall C	Activity Beam	•	s	HMS Co	nstruc	tion/Installati	on —	→Comm.		
Hall D	Activity Beam	<b>∢</b> — Glu	ıeX Insta	llation →	Comm.	Comm.	Physic	Physics		

Beam for Commissioning Beam for Physics Non-CLAS12 Ops





### **JLab: 21st Century Science Questions**

- What is the role of gluonic excitations in the spectroscopy of light mesons? Can these excitations elucidate the origin of quark confinement?
- Where is the missing spin in the nucleon? Is there a significant contribution from valence quark orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through measurements of new multidimensional distribution functions?
- What is the relation between short-range N-N correlations and the partonic structure of nuclei?
- Can we discover evidence for physics beyond the standard model of particle physics?





### **12 GeV Approved Experiments by Physics Topics**

Торіс	Hall A	Hall B	Hall C	Hall D	Other	Total
The Hadron spectra as probes of QCD (GluEx and						
heavy baryon and meson spectroscopy)		1		2		3
The transverse structure of the hadrons (Elastic and						
transition Form Factors)	4	3	2	1		10
The longitudinal structure of the hadrons						
(Unpolarized and polarized parton distribution functions)	2	3	6			11
The 3D structure of the hadrons (Generalized Parton						
Distributions and Transverse Momentum Distributions)	5	9	4			18
Hadrons and cold nuclear matter (Medium modification						
of the nucleons, quark hadronization, N-N correlations						
hypernuclear spectroscopy few-body experiments)	4	2	6		1	13
low operav tests of the Standard Model and					•	
Eundamontal Symmetries	2	1		1	1	6
	3					U
TOTAL	18	19	18	4	2	61





### **12 GeV Approved Experiments by PAC Days**

Торіс	Hall A	Hall B	Hall C	Hall D	Other	Total
The Hadron spectra as probes of						
QCD (GluEx and heavy baryon and						
meson spectroscopy)		119		320		439
The transverse structure of the hadrons						
(Elastic and transition Form Factors)	144	85	102	25		356
The longitudinal structure of the hadrons						
(Unpolarized and polarized parton						
distribution functions)	65	230	165			460
The 3D structure of the hadrons						
(Generalized Parton Distributions and						
Transverse Momentum Distributions)	409	872	161			1442
Hadrons and cold nuclear matter (Medium						
modification of the nucleons, quark						
hadronization, N-N correlations,						
hypernuclear spectroscopy, few-body						
experiments)	159	120	179		14	472
Low-energy tests of the Standard Model						
and Fundamental Symmetries	547	205		79	60	891
	1324	1631	607	424	74	4060
More than 7 ve	ars of	approv	ed ex	perimen		







## **12 GeV Scientific Capabilities**

Hall D – exploring origin of confinement by studying exotic mesons





Hall B – understanding nucleon structure via generalized parton distributions

Hall C – precision determination of valence quark properties in nucleons and nuclei





Hall A –form factors, future new experiments (e.g., SoLID and MOLLER)





### **Beyond 12 GeV Upgrade**

- Super BigBite Spectrometer (FY13-16 construction)
  - high Q<sup>2</sup> form factors
  - SIDIS
- MOLLER experiment (MIE – FY15-18?)
   Standard Model Test
- SoLID
   Chinese collaboration
   CLEO Solenoid ✓
  - Enhancements of equipment in B, C, D (Leverage external investments)









### **Quantum Numbers of Hybrid Mesons**



Gluonic excitation (and parallel quark spins) lead to exotic J<sup>PC</sup>





#### **Isovector Meson Spectrum**





TOF

Solenoid

## **The Incomplete Nucleon: Spin Puzzle**



• **DIS**  $\rightarrow \Delta \Sigma \cong$  **0.25** 

• RHIC + DIS  $\rightarrow \Delta G \ll 1$ 

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + J_g$$









## **Unified View of Nucleon Structure**





### **SIDIS Electroproduction of Pions**



- Sivers angle, effect in distribution function:  $(\phi_h \phi_s)$
- Collins angle, effect in fragmentation function:  $(\phi_h + \phi_s)$



## SIDIS Studies with 12 GeV at JLab

CLAS12 in Hall B

General survey, medium lumi



• SHMS- HMS in Hall C

L-T studies, precise  $\pi^+/\pi^-$  ratios

• SBS in Hall A

High x, High Q<sup>2</sup>, 2-3D

SOLID in Hall A

High Lumi and acceptance - 4D







### **Parity Violation at JLab**

- Nucleon Strangeness Form Factors (complete)
   HAPPEX (Hall A)
   G0 (Hall C)
- Neutron Skin
   PREX
  - CREX



- Precision Tests of Standard Model
  - Qweak (Under analysis)
  - MOLLER
  - SoLID





#### **Projected Results**





### **Cosmology and Dark Matter**



- Dark sector is new physics, beyond the standard model
  Many direct searches for dark matter interacting with sensitive detectors (hints, no established signal yet...)
- Controversial evidence for excess astrophysical positrons...





### **PAMELA Data on Cosmic Radiation**



Could indicate low mass A' (M<sub>A'</sub> < 1 GeV)</li>
 Or local astrophysical origin??





### **PAMELA Data on Cosmic Radiation**



Or local astrophysical origin??



DM

### New Opportunity: Search for A' at Jefferson Lab

- BNL "g-2" expt:  $\Delta a_{\mu}$ (expt-thy) = (295±88) x 10<sup>-11</sup> (3.4  $\sigma$ )
- No evidence for SUSY at LHC (yet)
- Another solution: A', a massive neutral vector boson



- 3 Jefferson Lab proposals:
  - APEX test run (Hall A) published PRL 107, 191804 (2011)
  - HPS test run (Hall B) complete
  - DarkLight test run (FEL) complete



mm



# MEIC Medium Energy EIC@JLab



#### JLab Concept

- Initial configuration (MEIC):
  - 3-11 GeV on 20-100 GeV ep/eA collider
  - fully-polarized, longitudinal and transverse
  - luminosity: up to few x 10<sup>34</sup> e-nucleons cm<sup>-2</sup>
- Upgradable to higher energies
   250 GeV protons + 20 GeV electrons







### **Jefferson Lab: Today and Tomorrow**

- The Jefferson Lab electron accelerator is a unique world-leading facility for nuclear physics research
   12 GeV commissioning well underway
- 12 GeV upgrade ensures at least a decade of excellent opportunities for discovery
  - New vistas in QCD
  - Growing program Beyond the Standard Model
  - Additional equipment: SBS, MOLLER, SoLID
- EIC moving forward:
  - Strong science case, much builds on JLab 12 GeV program
  - MEIC design well developed time scale following 12 GeV program is "natural"
  - NSAC Long Range Plan Imminent



