

# Jefferson Lab Science Overview

**Bob McKeown**

User Group Meeting  
June 22, 2020



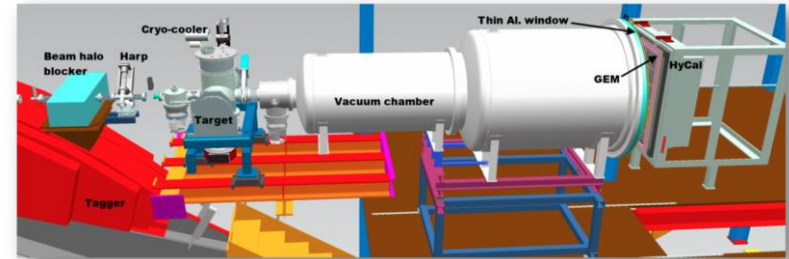
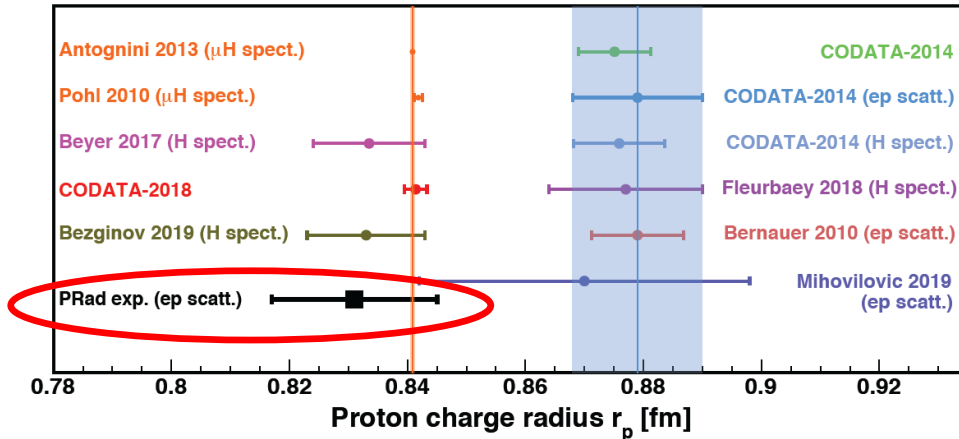
# Outline

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- Recent Highlights
- 12 GeV Program, PAC
- Future Projects
- Computing Initiatives
- Summary

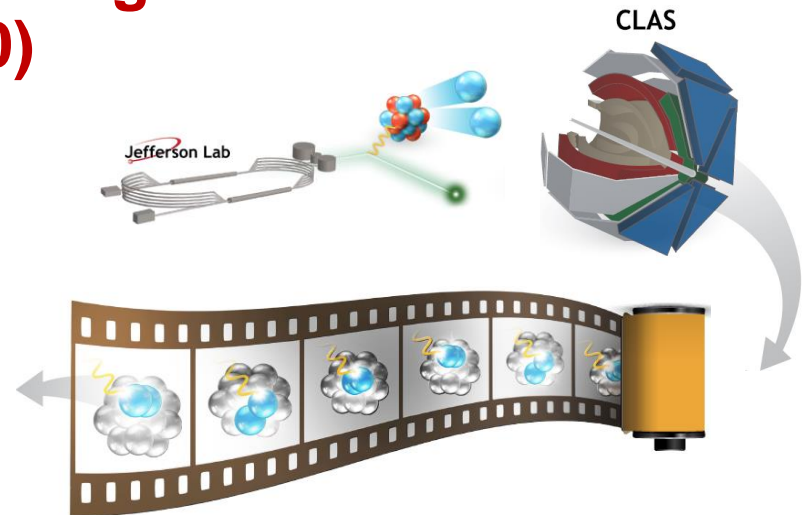
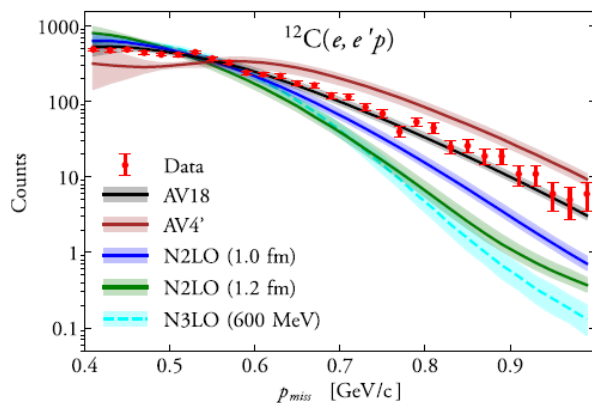
# JLab Results in *Nature*

- PRad: *Nature* 575, 147–150 (2019)**



Note: PDG has adopted PRad result for e-p scattering, with new average radius of 0.841 fm

- Probing the core of the strong nuclear interaction: *Nature* 578, 540-544 (2020)**



- Also - “Deeply virtual Compton scattering off the neutron”, *Nature Physics* 16, 191–198(2020)

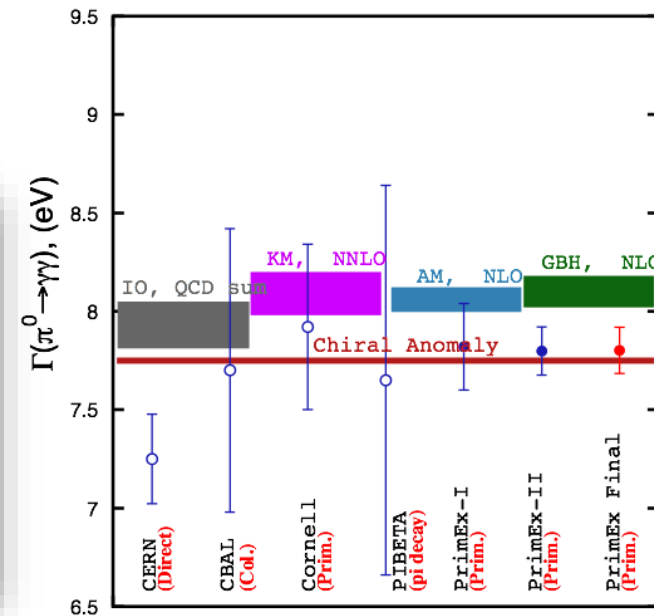
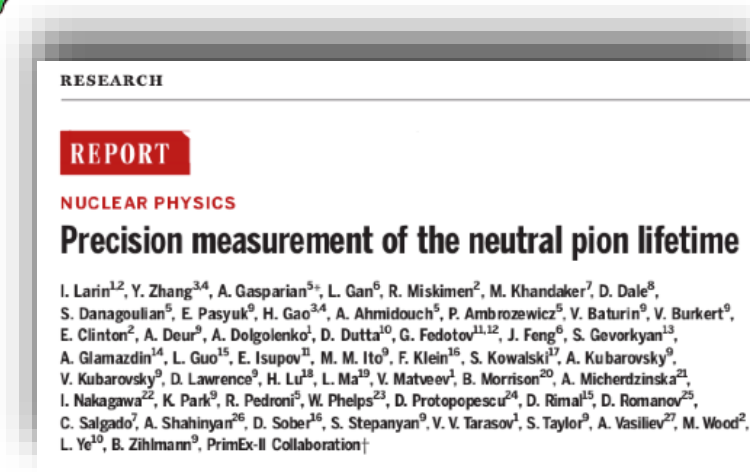
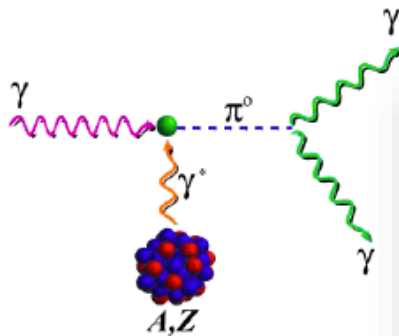


# Primakoff Experiment

**PrimEx**

## A Precision Measurement of the $\pi^0$ Radiative Decay Width via the Primakoff Effect

Science 01 May 2020:  
Vol. 368, Issue 6490, pp. 506-509  
DOI: 10.1126/science.aay6641

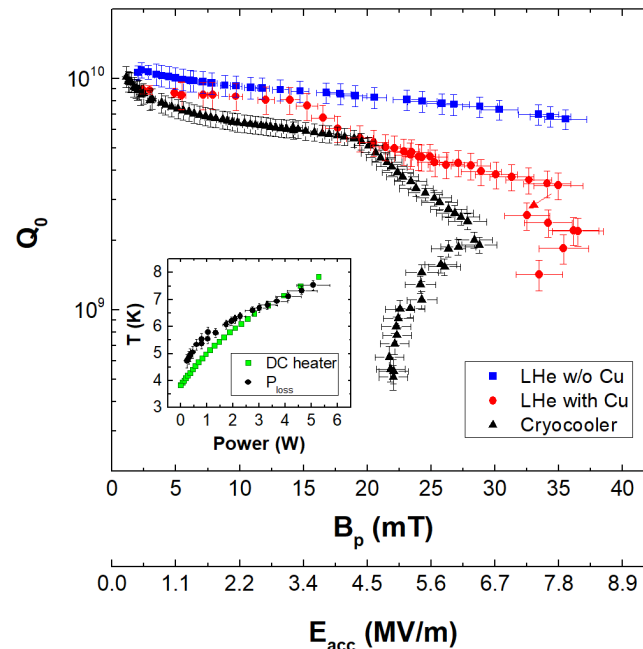
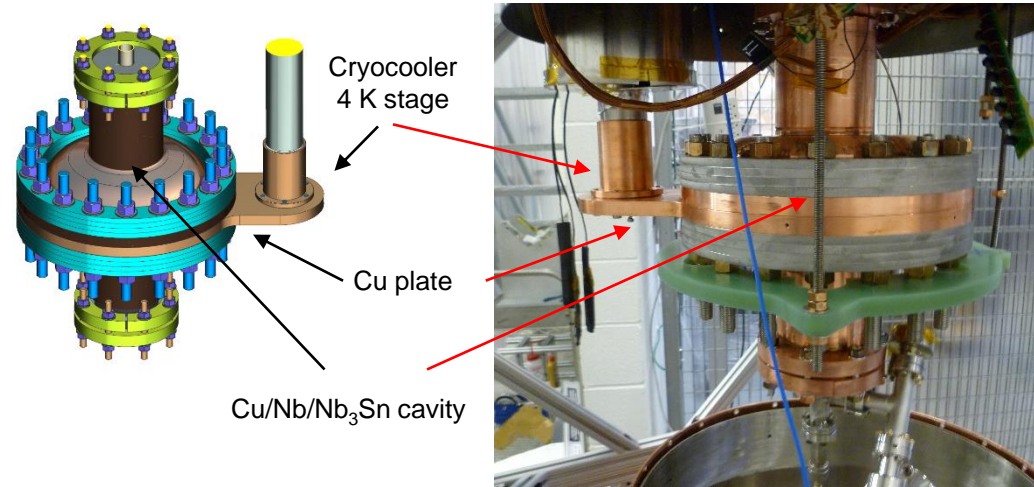


Theory and Experiments

- Precise measurement of  $\pi^0$  two-photons decay width
- Precise test of chiral symmetry and anomalies
- PrimEx final results **published in Science**

# Demonstration of Conduction-cooled SRF Cavity

- **Cu/Nb/Nb<sub>3</sub>Sn** 1.5 GHz single-cell cavity
- Commercial Gifford-McMahon **cryocooler**
- The cavity is cooled to ~4 K by conduction only, **no LHe!**
- The cavity was operated up to 5 W of power dissipation, 6.5 MV/m accelerating gradient
- The performance was limited by defects in the Nb<sub>3</sub>Sn film. Better Nb<sub>3</sub>Sn coatings are being developed
- Major step towards compact, low-cost accelerators for applications in industry, medicine or university-scale research.



G. Ciovati, G. Cheng,  
U. Pudasaini, and R.  
Rimmer,  
**Supercond. Sci.  
Technol.** 33 (2020)  
07LT01

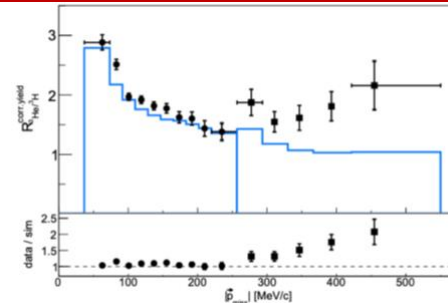
arXiv:2001.10924

*Work supported by Accelerator R&D  
funding and PECase Award of G. Ciovati*

# 12 GeV Science Era in Full Swing!

## Hall A:

- Tritium family of experiments – all 4 complete!
- Completed APEX (search for heavy photons)
- PREX complete, running CREX



<https://doi.org/10.1016/j.physletb.2019.134890>  
Editor's choice PRL:

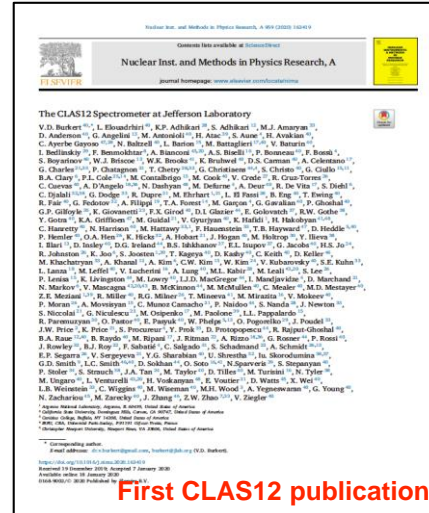
<https://doi.org/10.1103/PhysRevLett.124.212501>

## Hall B:

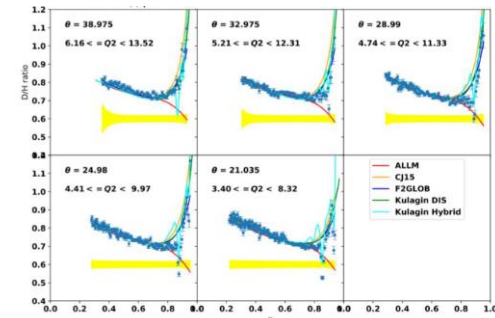
- First phase of CLAS12 Run Groups A & B complete
- PRad results published in Nature
- Heavy Photon Search planned 2019 run complete

## Hall C:

- 5.9 experiments completed
- $F_2^d/F_2^p$  preliminary result
- Search for LHCb pentaquark complete
- $A_1^n$  running complete



First CLAS12 publication!



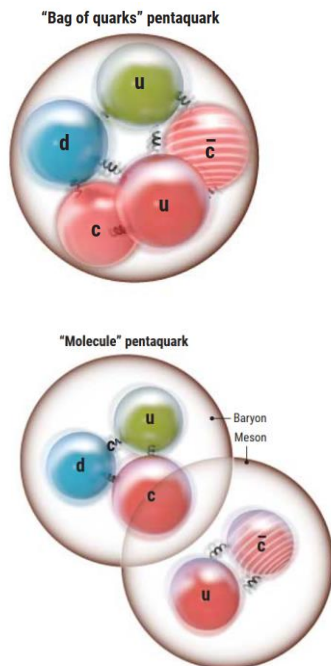
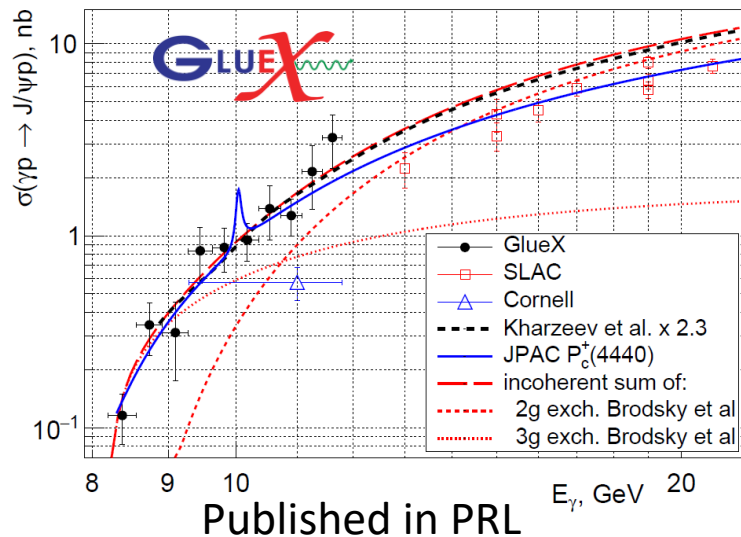
• D/H at high x

## Hall D:

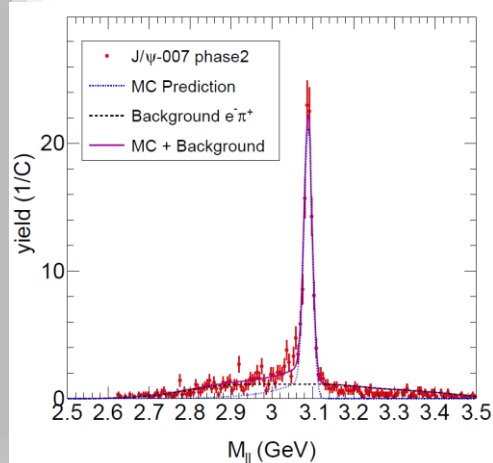
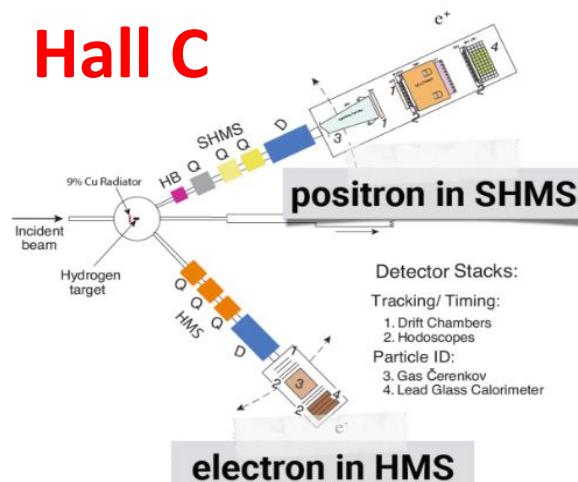
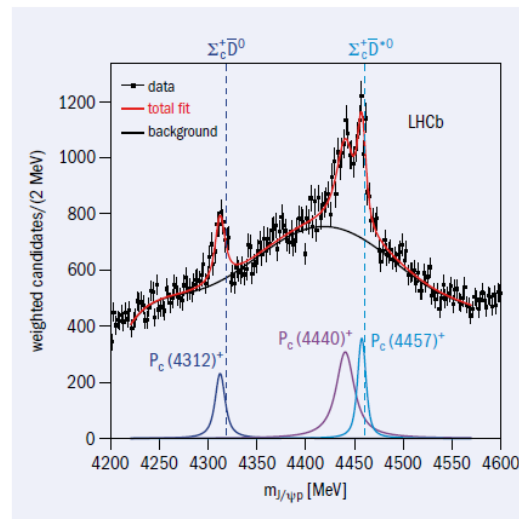
- GlueX phase I complete
- Threshold  $J/\psi$  published in PRL
- DIRC enhancement complete
- Phase II started

# Pentaquarks

$$\gamma p \rightarrow P_c \rightarrow J/\psi p$$



LHCb (2019)



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Science | AAAS



The Large Hadron Collider beauty experiment has discovered three new pentaquarks. PETER GINTER/CERN

Exotic particles called pentaquarks may be less weird than previously thought

**Jefferson Lab**

# Jefferson Lab Theory Center

## Hadron spectroscopy

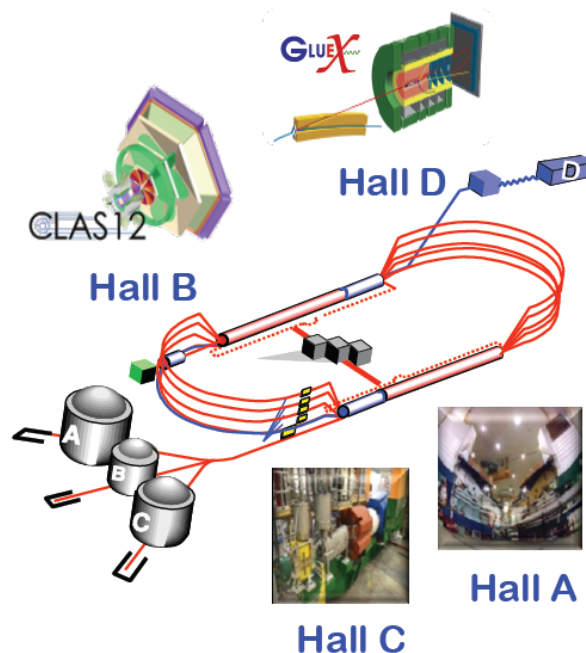
– **LQCD:** Briceno, Edwards, Dudek, Orginos, Richards

## Hadron spectroscopy

– **JPAC:** Briceno, Passemar, Szczepaniak

## Structure of nuclei

( $A > 1$ ): Schiavilla, Van Orden, Weiss



## Hadron/nuclear structure

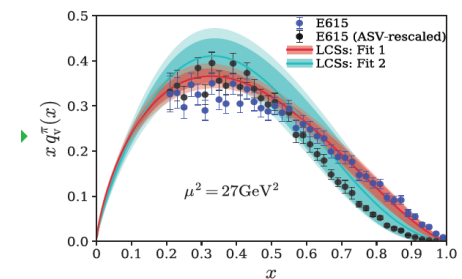
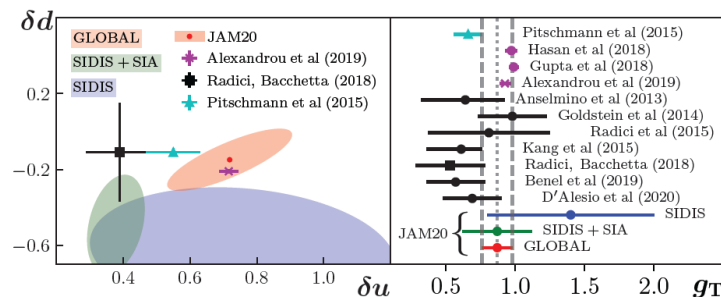
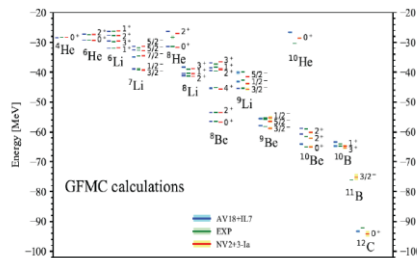
– **LQCD:** Briceno, Edwards, Monahan, Orginos, Qiu, Radyushkin, Richards

## Hadron/nuclear structure

– **Partonic:** Accardi, Balitsky, Melnitchouk, Prokudin, Qiu, Radyushkin, Rogers

## Hadron/nuclear structure

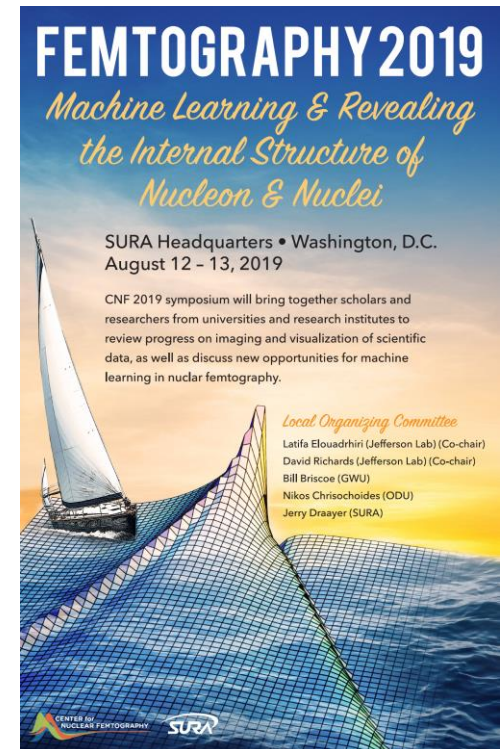
– **Hadronic & EFTs:** Goity, Melnitchouk, Van Orden, Szczepaniak, Weiss





# Virginia Center for Nuclear Femtography

- Funded by Commonwealth to “.....to facilitate the application of modern developments in **data science** to the problem of imaging and visualization of sub-femtometer scale structure of protons, neutrons, and atomic nuclei”
  - Seven joint lab/university initiatives funded by the Commonwealth of Virginia
- Multi-disciplinary, bringing together *nuclear theorists and experimentalists, mathematicians, computer scientists, ... .. and architects and artists!*
- Director: Xiangdong Ji



# PAC47 Results

NUMBER	TITLE	CONTACT PERSON	HALL	DAYS REQUESTED	DAYS AWARDED	SCIENTIFIC RATE	PAC DECISION
<b>New Proposals</b>							
PR12-19-001	Strange Hadron Spectroscopy with Secondary KL Beam in Hall D	Moskov Amaryan	D	200			C2
PR12-19-002	High precision measurement of Lambda hyperhydrogens	Toshiyuki Gogami	A	12			C2
PR12-19-003	Studying Short-Range Correlations with Real Photon Beams at GlueX	Or Hen	D	30	15	B+	Approved
PR12-19-004	Search for a $\phi$ -N Bound State from $\phi$ Production in a Nuclear Medium	Haiyan Gao	B	45			Deferred
PR12-19-005	Beam-Dump Dark Matter Search Utilizing a Low-Threshold, Directional Dark Matter Detector (BDX-DRIFT) at Jefferson Lab	Daniel Snowden-Ifft	A	285			Deferred

# PAC47 Results (Jeopardy)

NUMBER	TITLE	CONTACT PERSON	HALL	DAYS REQUESTED	DAYS AWARDED	SCIENTIFIC RATE	PAC DECISION
<b>JEOPARDY PROPOSALS</b>							
E12-07-109	Large Acceptance Proton Form Factor Ratio Measurements up to 14.5 GeV <sup>2</sup> Using the Recoil-Polarization Method	Bogdan Wojtsekhowski	A	45		A-	
E12-06-105	Inclusive Scattering from Nuclei at $x > 1$ in the quasielastic and deeply inelastic regimes	Donal Day	C	32		A-	
<del>E12-06-101</del> <del>E12-07-105</del> E12-19-006	Update on E12-06-101: Measurement of the Charged Pion Form Factor to High $Q^2$ and E12-07-105: Scaling Study of the L-T Separated Pion Electroproduction Cross Section at 11 GeV	Garth Huber	C	88		A	
E12-06-107	Hadron Propagation and Color Transparency at 12 GeV	Dipangkar Dutta	C	17.5		B+	
E12-06-114	Measurements of the electron-helicity dependent cross sections of deeply virtual Compton scattering in Hall A at 11 GeV	Charles Hyde	A C	50	35	A	
E12-06-104	Measurement of the Ratio $R = \sigma_L / \sigma_T$ in Semi-Inclusive Deep-Inelastic Scattering	Rolf Ent	C	40		A	Upgraded to A

# PAC Approved experiments (status at May 1<sup>st</sup>)

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
Hadron spectra as probes of QCD	0	2	1	3	0	6
Transverse structure of the hadrons	6	3	3	1	0	13
longitudinal structure of the hadrons	1	3	7	0	0	11
3D structure of the hadrons	4.5	9	5.5	0	0	19
Hadrons and cold nuclear matter	8	5	7	1	0	21
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	1	6
<b>Total</b>	<b>22.5</b>	<b>23</b>	<b>23.5</b>	<b>6</b>	<b>1</b>	<b>76</b>
<b>Total Experiments Completed</b>	<b>8.6</b>	<b>8.7</b>	<b>6.8</b>	<b>1.4</b>	<b>0</b>	<b>25.5*</b>
<b>Total Experiments Remaining</b>	<b>13.9</b>	<b>14.3</b>	<b>16.7</b>	<b>4.6</b>	<b>3.0</b>	<b>50.5</b>

**\* Equivalent to 14 fully completed and 21 partially completed experiments**



# 12 GeV Experiments by PAC Days (status at May 1<sup>st</sup>)

Topic	Hall A	Hall B	Hall C	Hall D	Total
Hadron spectra as probes of QCD	0	219	11	540	770
Transverse structure of the hadrons	150.5	85	146	25	406.5
Longitudinal structure of the hadrons	19	230	211	0	460
3D structure of the hadrons	359	872	196	0	1427
Hadrons and cold nuclear matter	220	275	205	15	715
Low-energy tests of the Standard Model and Fundamental Symmetries	547	180	0	79	806
<b>Total Days</b>	<b>1295.5</b>	<b>1861.0</b>	<b>769.0</b>	<b>659</b>	<b>4584.5</b>
<b>Total Days - (includes MOLLER)</b>	<b>821.5</b>	<b>1861</b>	<b>769</b>	<b>659</b>	<b>4110.5</b>
<b>Total Approved Run Group Days (includes SoLID)</b>	<b>1295.5</b>	<b>1026</b>	<b>726</b>	<b>459</b>	<b>3506.5</b>
<b>Total Approved Run Group Days (includes MOLLER)</b>	<b>821.5</b>	<b>1026</b>	<b>726</b>	<b>459</b>	<b>3032.5</b>
<b>Total Days Completed</b>	<b>240.5</b>	<b>283</b>	<b>159.0</b>	<b>184</b>	<b>866.5</b>
<b>Total Days Remaining</b>	<b>581</b>	<b>743</b>	<b>567</b>	<b>235</b>	<b>2166</b>

+167 (PAC) days completed in FY20 to date

**A DECADE OF EXCELLENT SCIENCE!**

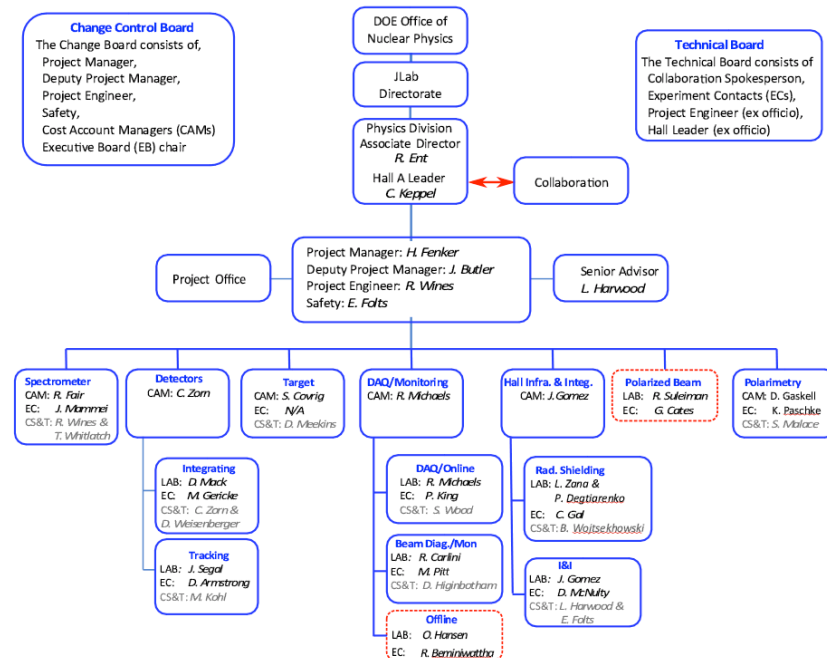
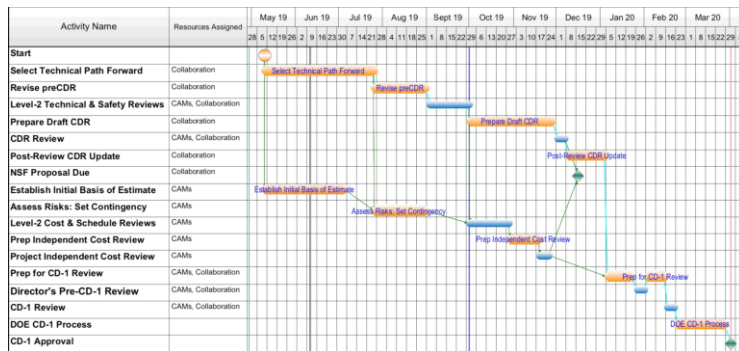
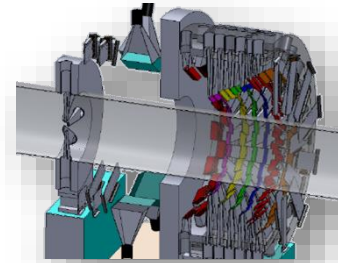
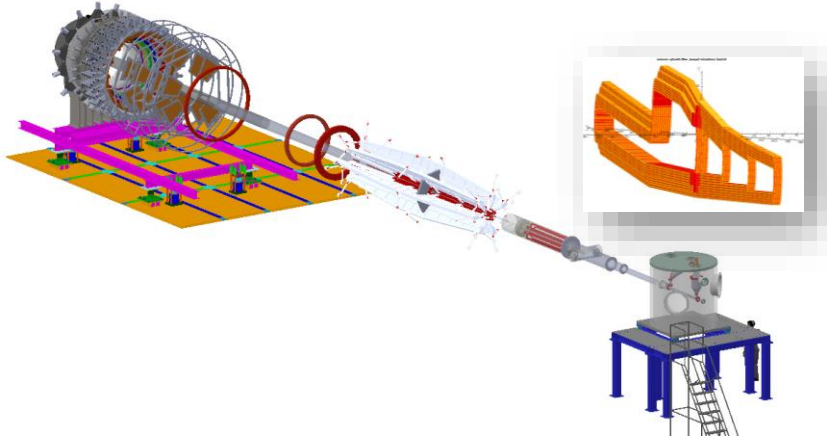
# PAC48

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- Aug. 10 - August 14, 2020
- Proposals were due June 22
- New chair: Markus Diehl
- New members: Elke Aschenauer, Shinya Sawada, Concettina Sfienti, Feng Yuan
- Will continue Jeopardy process...

# MOLLER Progress

- January 14-16, 2020 Director's Review
- Project manager: Jim Fast
- Planning for summer DOE CD-1 Review Sept. 22-24, 2020



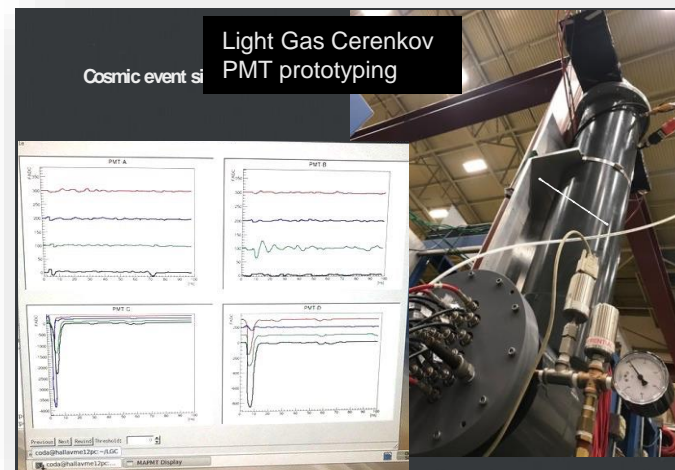
Control Account Managers (CAM), Lab. L2 (LAB), Experiment Contact (EC), Reviewer (CS&T)

# SoLID Activities

- Director's Review (Sept. 9-11)
  - 5 recommendations
  - Many comments
- Submitted proposal to ONP – Feb. 2020
- Anticipating Science Review to follow

JLab CLEO-II magnet CE funding:

- Outer steel from Cornell - July 2019
- Prep for Magnet Static Tests
- Magnet instrumentation & controls
  - purchases and work ongoing
- Prep for Cryo Reservoir work

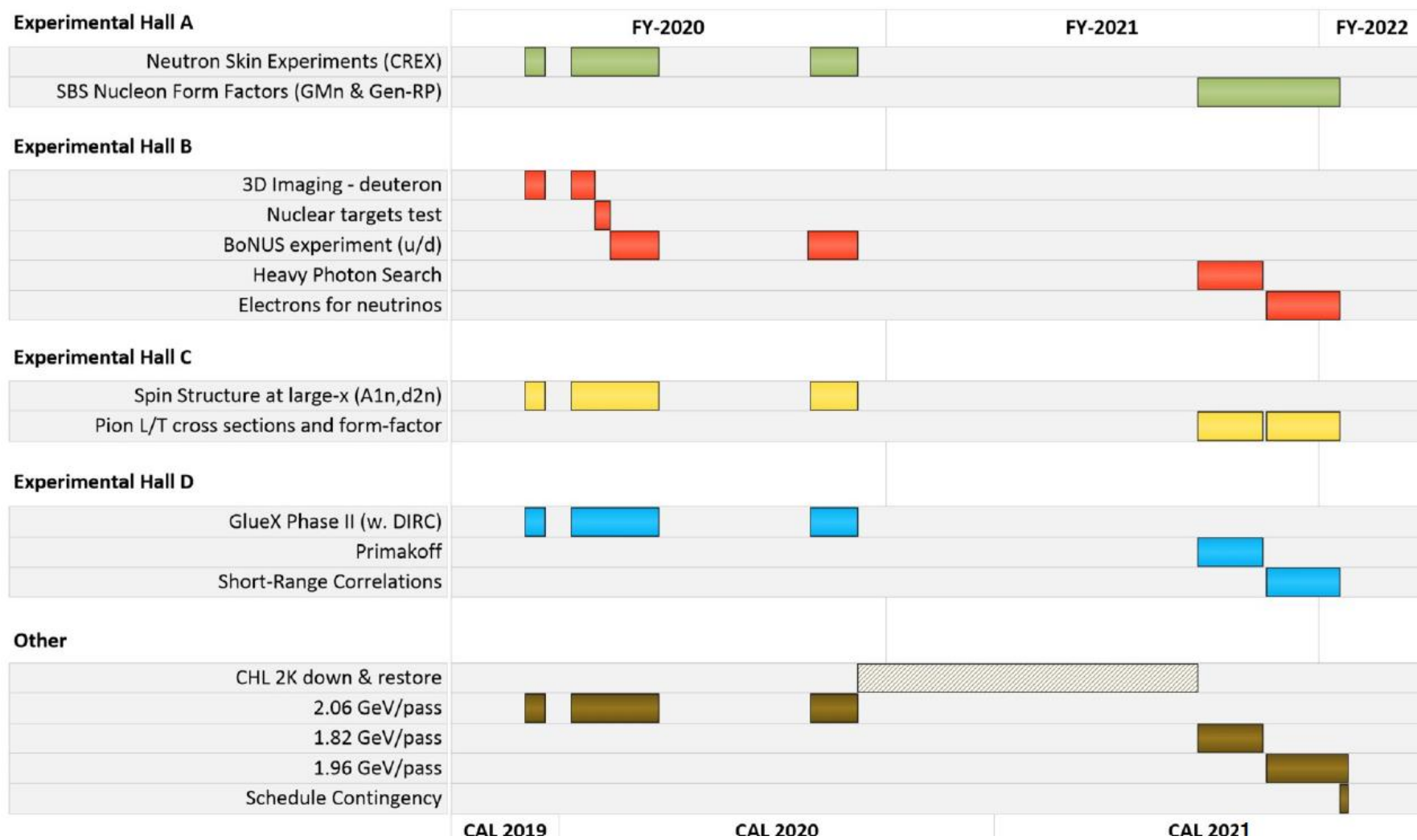


Collaboration working on pre-R&D

- ECal fiber testing
- LGC background test with prototype, mirror study
- HGC performance simulations w. different options, gas system
  - window test



# Published FY20-21 Schedule



# Advanced Computing Initiatives

*Computation is crucial to all aspects of our NP Program.*

- Initiative 1: Integrated Start to End Experimental Computing Model for 12 GeV Physics Program and future EIC
- Initiative 2: Develop computational and data science methodology and infrastructure to realize the scientific goals of Nuclear Femtography
- Initiative 3: Apply Machine Learning for accelerator modeling/control



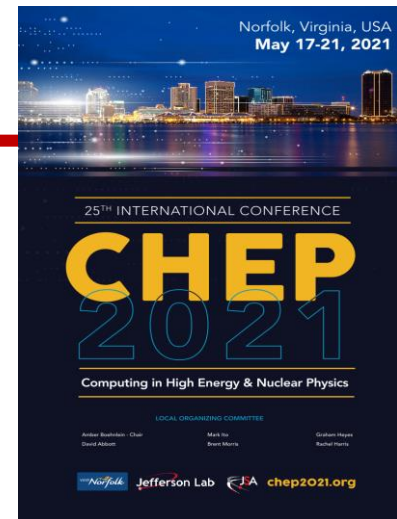
**A.I.**  
for Nuclear Physics

**March 4-6, 2020**

The A.I. for Nuclear Physics workshop will explore the ways in which A.I. can be used to advance research in fundamental nuclear physics and in the design and operation of large-scale accelerator facilities.

[www.jlab.org/conference/AI2020](http://www.jlab.org/conference/AI2020)

- >180 Attendees!
- Report writing in progress

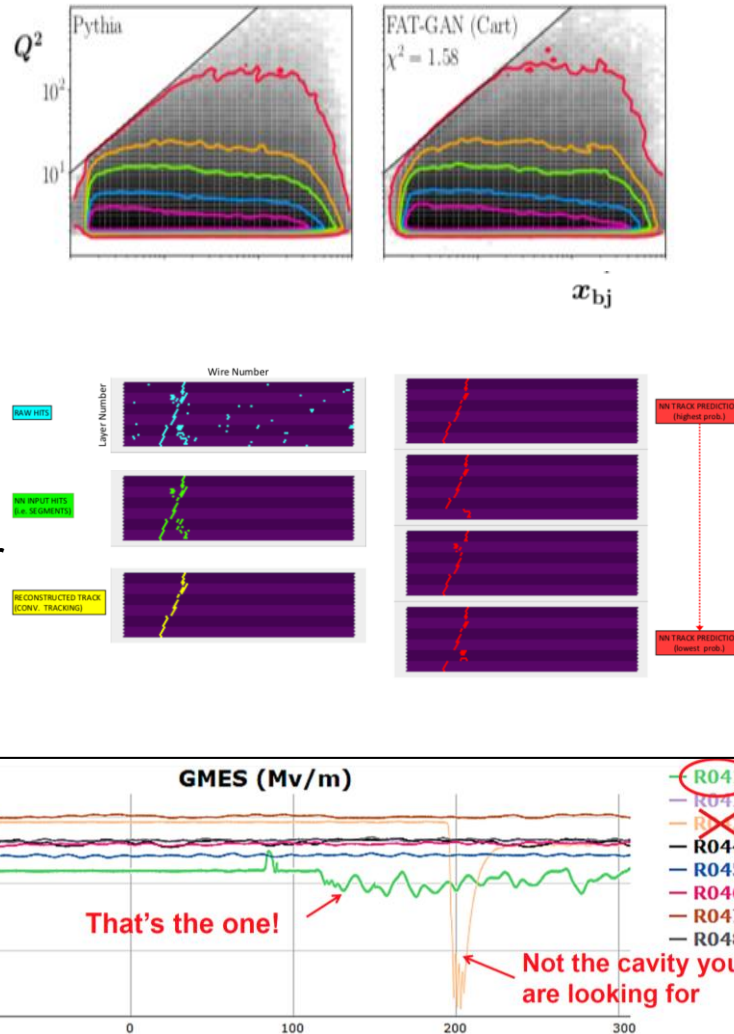


- Streaming readout simultaneously on 7 CLAS12 subsystems
- Integration of LQCD results as data source in global fits
- LDRD in progress for A.I. for accelerators
- Quantum Simulation mini lecture series
- Hosting A.I. for Nuclear Physics Workshop
- Selected as host for Computing in High Energy and Nuclear Physics, 2021

# A.I. : Enabling Technology

*Data Science is a component of all Advanced Computing Initiatives:  
recent progress*

- Theory: Using Generative Adversarial Networks to extract observables from data (LDRD)
  - Generated Pythia sample used to check methodology
- Experiment: CLAS12 using Neural Network to determine the segments that belong to valid tracks
  - Preliminary results 96% accuracy and factor of 6 faster for this class of events
- Accelerator: Use data from CEBAF to diagnose and improve operational performance (LDRD)
  - Significant progress applying machine learning to the problem of classifying C100 cavity faults



- Re-organization to foster A.I.
- Lunch and Learn Weekly Community of Practice
- Hiring A.I. Developer
- Lab wide regular Machine Learning Challenge Contest
- Satellite Site for Pittsburgh Super Computing Center Big Data Training programs
- A.I. Hackathon March 3, 2020
- AI for Nuclear Physics Workshop March 4-6, 2020

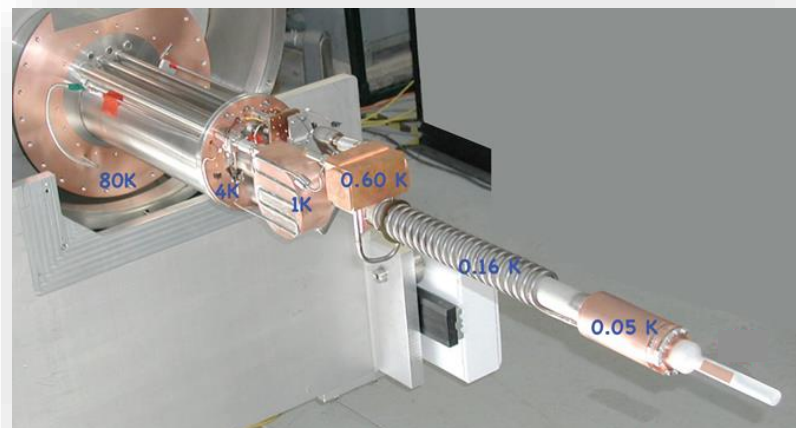
# Jefferson Lab Opportunity: Quantum Computing

Preamble: There have been significant advances in QIS in recent years

- Algorithm development for nuclear theory
- Studying Hamiltonians to develop QC algorithms is likely to pay dividends in classical approaches
- Availability and access to experimental hardware platforms will ultimately be key to progress
- Analogous to early days of LQCD

**QIS Testbed is well-suited to JLab's core strengths:**

- **Quantum Field Theory**
- **Advanced Computation/Software**
- **Algorithm Development**
- **SRF**
- **Cryogenics**
- **Ultracold technologies (<20 mK)**



*JLab Cryogenic Polarized Target*

- **Lecture series funded by ONP – March 2020**
- **Collaboration preproposals**
  - **BNL Center**
  - **Yale U. Center**
- **Encourage LDRD proposals**



# Summary

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- 12 GeV science program at JLab is underway
  - 4 Hall operation is now routine
  - A broad program of 76 approved experiments with many opportunities for discovery is planned
  - Initial science results are already being reported
- Future Equipment projects
  - MOLLER: CD0 – FY20 start, CD-1 review in Sept.
  - SoLID: Prepare for DOE science review
- Anticipate a unique program for CEBAF with fixed targets at the luminosity frontier, complementary to EIC, in the future.
- We continue to develop advanced computation at Jlab, including AI/ML and QIS