J-FUTURE

March 28, 2022 - March 30, 2022 • Messina, Italy

The Jefferson Lab of the Future

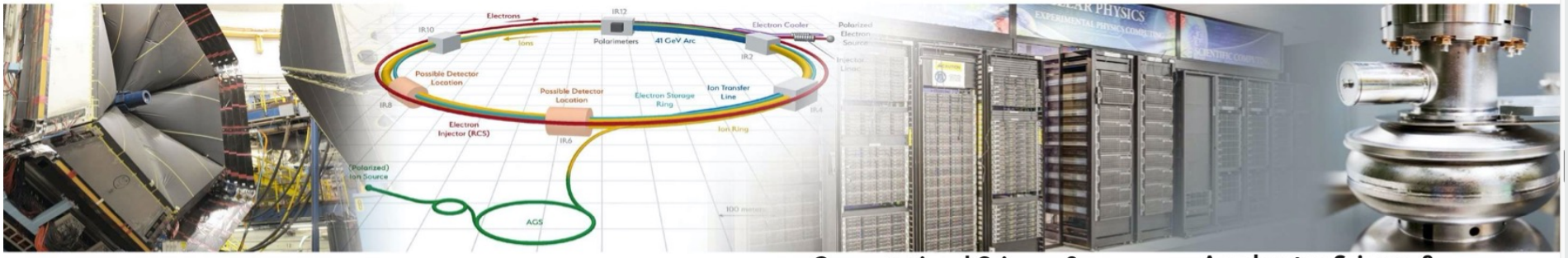
Patrizia Rossi

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Jefferson Lab's Science and Technology Vision



Nuclear Physics at CEBAF

Vibrant 12 GeV research program, operating >30 weeks/yr, supporting 1,700 annual users

MOLLER Project & SoLID proposal

Future opportunities in fixed-target, high-luminosity complementary to EIC

Theory and computation supporting NP goals

Electron-Ion Collider

Partnering with BNL in the management, design, and construction of the Electron-Ion Collider Project

Leadership in EIC scientific program

Computational Science & Technology

Vision for world-leading computational program

Developing concept of a High Performance Data Facility focused on the unique challenges and opportunities for data-intensive applications and near real-time computing needs

Computational Nuclear Physics

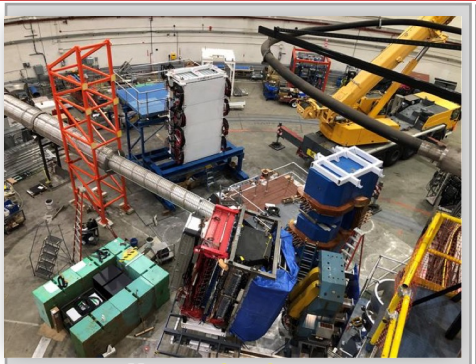
Accelerator Science & Technology

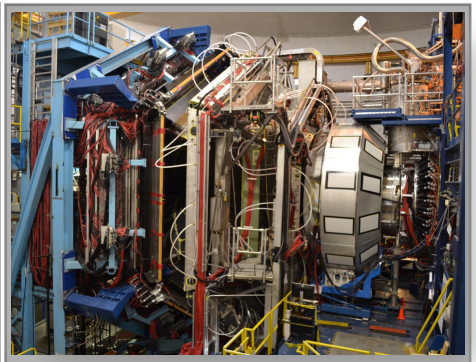
Accelerator component production for DOE/SC projects, including LCLS-II and LCLS-II-HE at SLAC, and SNS-PPU at ORNL

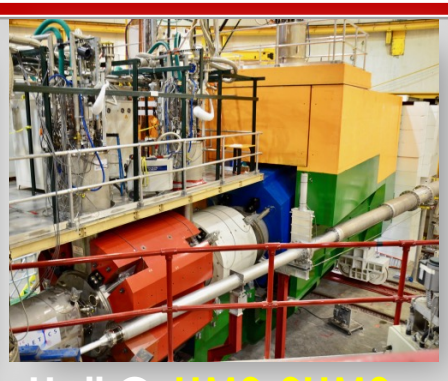
R&D in accelerators, detectors, isotopes

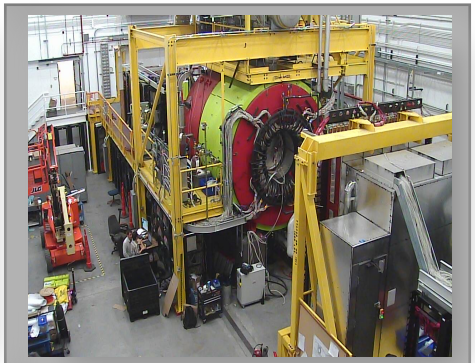
Jefferson Lab is facing a time of change!!

Today and Tomorrow


Hall A: SBS & BB

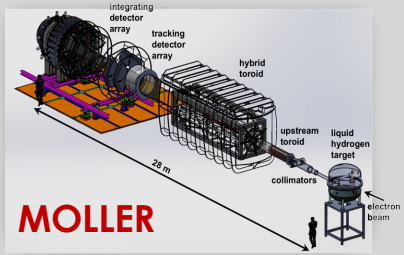

Hall B: CLAS12


Hall C: HMS-SHMS

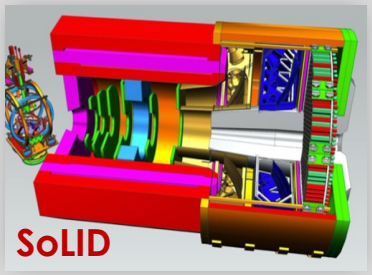

Hall D: GlueX

The 12 GeV Experimental Program is in full swing

~32 Experiments completed out of 86 approved

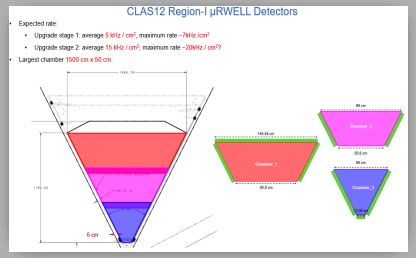


MOLLER

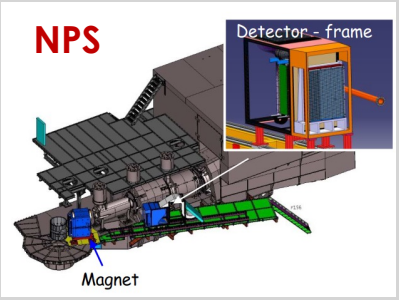

SoLID

Luminosity Upgrade

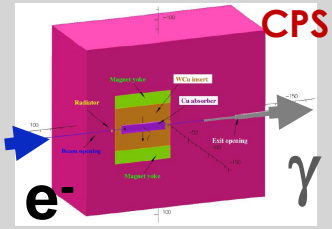
Stage -1: **$2x10^{35}cm^{-2}\ s^{-1}$**
3 years
Stage -2: > **$10^{37}cm^{-2}\ s^{-1}$**
7-10 years



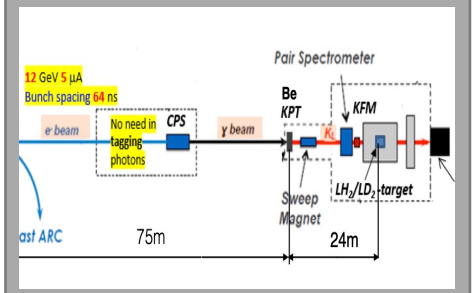
NPS



CPS



KLF



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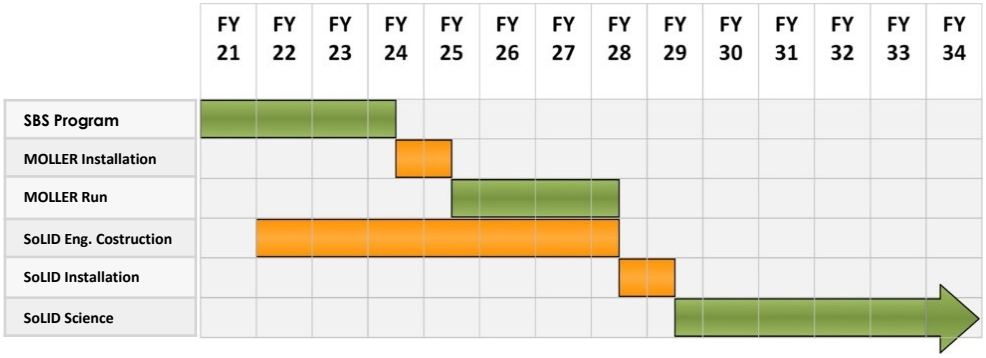
Near and Short Terms

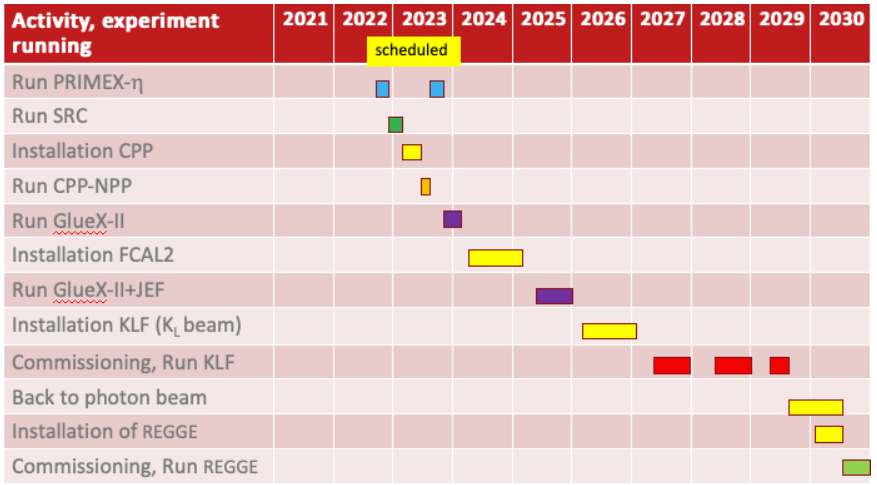
- Highest Priority is delivering on CEBAF 12 GeV Program
- Goal is > 30 weeks/year with reliable operation at required energy
- Executing CEBAF Performance Plan to improve energy and reliability
- Completing and Executing the MOLLER Project
- Moving SoLID forward (DOE Science Review held in March 2021)

JLab has to expand its time horizon beyond 2030 !!

Hall A Schedule



Hall D Schedule



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Possible Scenarios for future CEBAF

- Polarized positron beam (@12 GeV):
  - R&D ongoing
  - no major upgrades needed for both accelerator and detectors
- Luminosity Upgade
  - Beam dump upgrade

J. Grames & J. Benesch's talks tomorrow

- Energy ~24 GeV:
  - R&D ongoing

A. Bogacz 's talk tomorrow

Optimal Utilization of Cebaf

- ❖ Incremental funds
- ❖ Already included in our CE

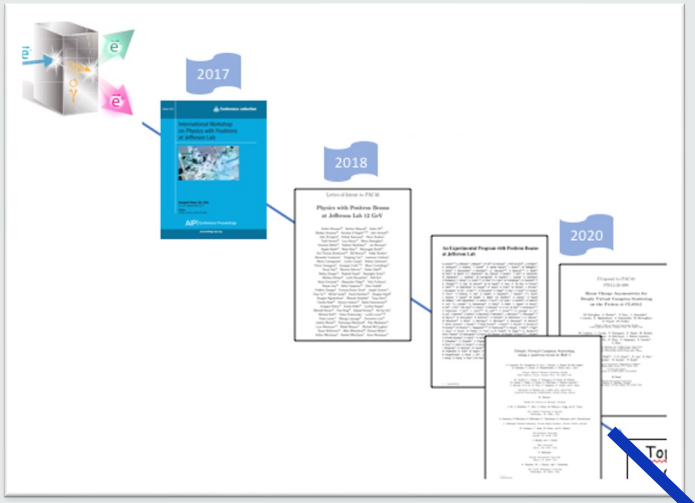
Cebaf Upgrade

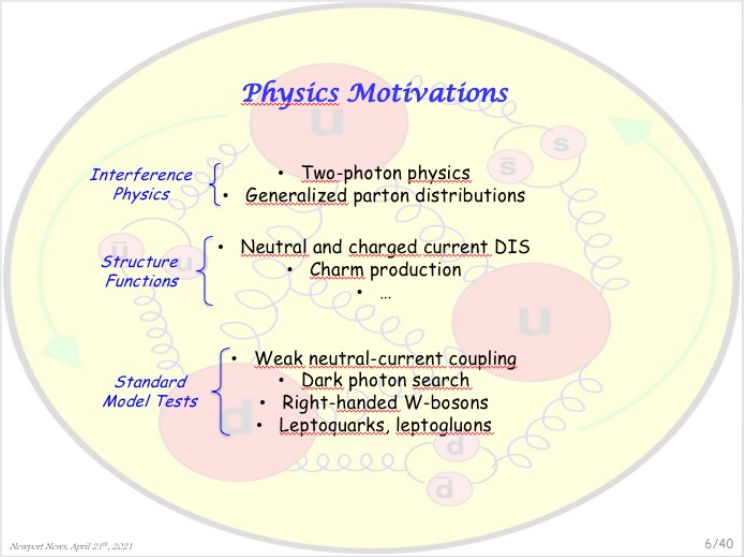
- ❖ DOE Approval
- ❖ Motivation for larger community

CEBAF with Positron Beam

- **PEPPo concept successfully demonstrated by measuring longitudinal positron polarization up to 82% corresponding to a polarization transfer of~ 100% from 8.19 MeV/c polarized electrons** (Phys. Rev. Lett. 116, 214801 (2016).

- **A PWG was created in 2017 to promote the physics case of a e^+ beam of high energy (up to 11 GeV), high current (I_{e+}~0.5-1uA), high pol. (P_{e+}~60%)**





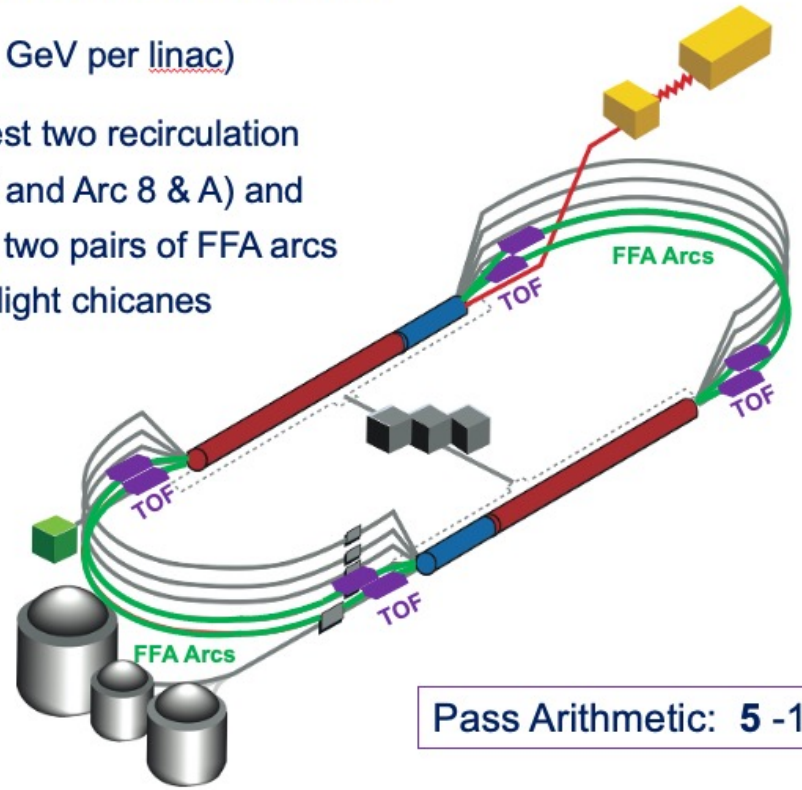
From JLab PAC48 Report: **August 2020**

"The Committee sees great physics potential in a positron program. We encourage a vigorous effort to explore the technical feasibility of providing positron beams, and we are looking forward to receiving further proposals in this area. Clearly, it is difficult at the present stage to predict the characteristics of positron beams that will be achievable."

- **EPJA Topical Issue: 20 contributions illustrating the benefit of positrons for different physics**

CEBAF FFA Upgrade – 'Big Picture'

- Starting with 12 GeV CEBAF as a baseline
- NO new SRF (1.1 GeV per linac)
- Remove the highest two recirculation passes (Arc 7 & 9 and Arc 8 & A) and replace them with two pairs of FFA arcs including time-of-flight chicanes



- Recirculate 11 times to get to 22-24 GeV:
  - 3 passes with the current CEBAF (Arcs 1-6)
  - 8 passes through a pair non-scaling FFAs (4 + 4)
  - CBETA-proven architecture
  - Novel permanent magnet CBETA technology used for power and cost savings

Pass Arithmetic: **5** -1 + 4 -1 + 4 = 3 + 8 = **11**

Cortesy A. Bogacz

- Cutting-edge Technology ➛ Support CEBAF's 4th pillar
- Sinergy with EIC ➛ Technology proposed for the ERL for the hadron cooling

Several Initiatives

- Update 2012 white paper

arXiV:2112.00060 - To be published by Progress in Particle and Nuclear Physics in 2022

Physics with CEBAF at 12 GeV and Future Opportunities

J. Arrington[1], M. Battaglieri[2], A. Boehnlein[2], S.A. Bogacz[2], W.K. Brooks[11], E. Chudakov[2], I. Cloët[3], R. Ent[2], H. Gao[4], J. Grames[2], L. Harwood[2], X. Ji[5,6], C. Keppel[2], G. Krafft[2], R. D. McKeown[2,8,*], J. Napolitano[7], J.W. Qiu[2], P. Rossi[2], M. Schram[2], S. Stepanyan[2], J. Stevens[8], A.P. Szczepaniak[9], N. Toro[10], X. Zheng[12]

  - 12 GeV program accomplishments
  - Planned program approved by PAC
  - Future opportunities: high luminosity, positron beam, higher energy

- Discussions for future opportunities at CEBAF (high luminosity, higher energy, positron beam) have been initiated during collaboration meetings and also in dedicated round table meetings

Very Active Community

https://indico.jlab.org/event/520/

J-FUTURE

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TOPICS

- Physics opportunities
- Hadron spectroscopy
- Nucleon structure
- Nuclear structure
- Detector developments

ORGANIZERS

M. Battaglieri (INFN Genova)
G. Mandaglio (Messina U. and INFN Catania)

Objective of the workshops is to gather theorists and experimentalists to discuss the physics opportunities and technical options for each of the possible upgrade scenarios: luminosity, energy, positron

APCTP Focus Program in Nuclear Physics 2022: Hadron Physics Opportunities with JLab Energy and Luminosity Upgrade

Jul 18 – 23, 2022
APCTP, Pohang
Asia/Seoul timezone

Enter your search term

Overview
Timetable
Participant List

The electroproduction of mesons and photons has been shown to be a powerful tool for studies of the interaction of elementary particles and their dynamics at short and long distances. In particular, studies of the orbital motion of partons encoded in transverse space and momentum distributions of partons, like Generalized Parton Distributions (GPDs) and Transverse Momentum Distributions (TMDs), have been widely recognized as key objectives of the JLab 12 GeV program. Studies of azimuthal distributions of hadrons and photons in exclusive and semi-inclusive DIS (SIDIS) provide access to variety of observables widely recognized as key objectives of the COMPASS measurements, various activities at RHIC and KEK, the LHC fixed target projects (LHC spin, SMOG2@LHCb) and a driving force behind the construction of the future Electron Ion Collider (EIC). Studies of the ground and excited nucleon state structure in terms of nucleon elastic form factors, PDFs, and the N→N* (nucleon to nucleon resonances) transition electro-excitation amplitudes offer a unique complementary opportunity to explore the evolution of active components in the structure of the ground and excited state nucleons at distances where the transition from quark-gluon confinement to the perturbative QCD regime is expected and where the dominant part of hadron mass emerges. These studies are of particular importance to address key open problems of the Standard Model on emergence of hadron mass and quark-gluon confinement. The upgraded to 24 GeV JLab, with much wider kinematical coverage, in particular at large Q^2, will be crucial to extend all ongoing projects at JLab, in particular studies of the 3D structure of hadrons and hadronization, pin down interaction dependent parts, providing missing deeper access to quark- gluon dynamics and opening new opportunities on studies of the charm sector and significant improvement in secondary

https://indico.knu.ac.kr/event/566/

OPPORTUNITIES WITH JLAB ENERGY AND LUMINOSITY UPGRADE

26 September 2022 — 30 September 2022

ECT* - Villa Tambosi

Strada delle Tabarelle, 286
Trento - Italy

https://www.ectstar.eu/workshops/opportunities-with-jlab-energy-and-luminosity-upgrade/

Organizers

Harutyun Avagyan (Jefferson Lab, Newport News/US)
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John Arrington (Lawrence Berkeley National Laboratory, Berkeley/US)
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Preparation for the Long Range Plan

- JLab is organizing a series of one-day workshops on **"JLab at Higher Energies"** to build a science case in preparation for the Long-Range Plan.

- The workshops aim to develop compelling physics arguments for energy upgrade and are looking for:
- Unique science in luminosity and precision frontier
- New avenues and key science questions accessible with E>20 GeV electron beams
- Complementarity with EIC

- Suggested topics:
- XYZ spectroscopy
- Anti-shadowing and the role of the sea
- Physics with charm
- The role of gluons in nucleon and nuclear structure
- The next generation of 3D imaging

Key Challenge_1

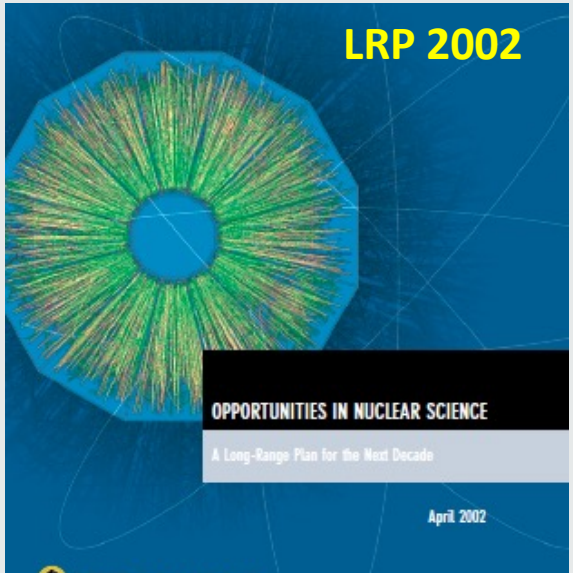
Accelerator

- The Cornell-BNL ERL Test Accelerator (CBETA) demonstrated simultaneous transport of multiple beams with energies spanning a factor of 4 through a single beamline.
- This wide energy bandwidth was achieved using the FFA principle
- CBETA's maximum energy was 150 MeV, whereas CEBAF upgrades plan to extend this technology to higher beam energies.

- Feasibility?
- Risks?
- Timeline?
- Cost?

Key Challenge_2

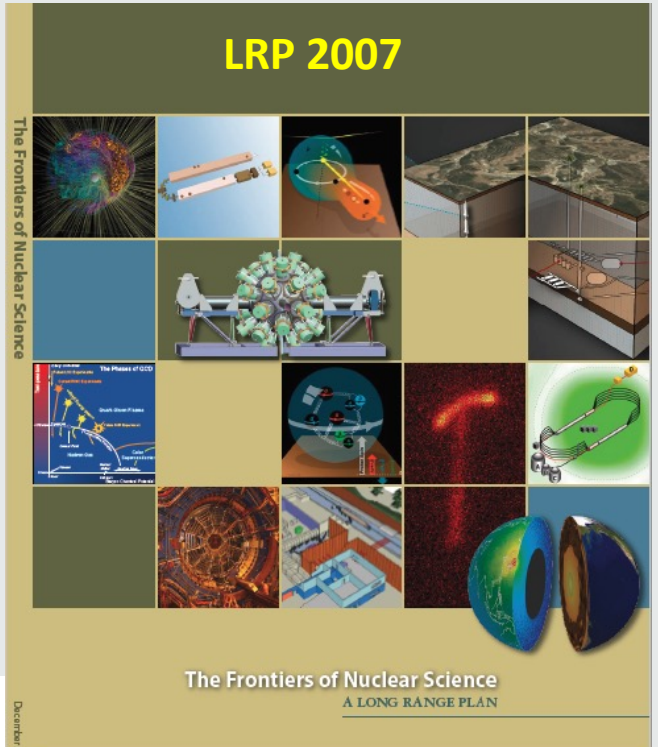
Physics Case: Identify key experiments motivating the facility



RECOMMENDATION 4

We strongly recommend the upgrade of CEBAF at Jefferson Laboratory to 12 GeV as soon as possible.

The 12-GeV upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This upgrade will provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of matter, and the nature of quark confinement.



RECOMMENDATION I

We recommend completion of the 12 GeV CEBAF Upgrade at Jefferson Lab. The Upgrade will enable new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of nuclei, and the nature of confinement.

New physics reach provided by the 12 GeV CEBAF Upgrade:

- Nuclear tomography to discover and explore the three-dimensional structure of the nucleon
- The search for exotic mesons—a quark and an anti-quark held together by gluons, but unlike conventional mesons, the gluons are excited
- Physics beyond the Standard Model via high precision studies of parity violation
- The spin and flavor dependence of valence parton distributions—the heart of the proton, where its quantum numbers are determined
- The structure of atomic nuclei, exploring how the valence quark structure is modified in a dense nuclear medium

From 6 to 12 to 24

JLab @ Higher Energies

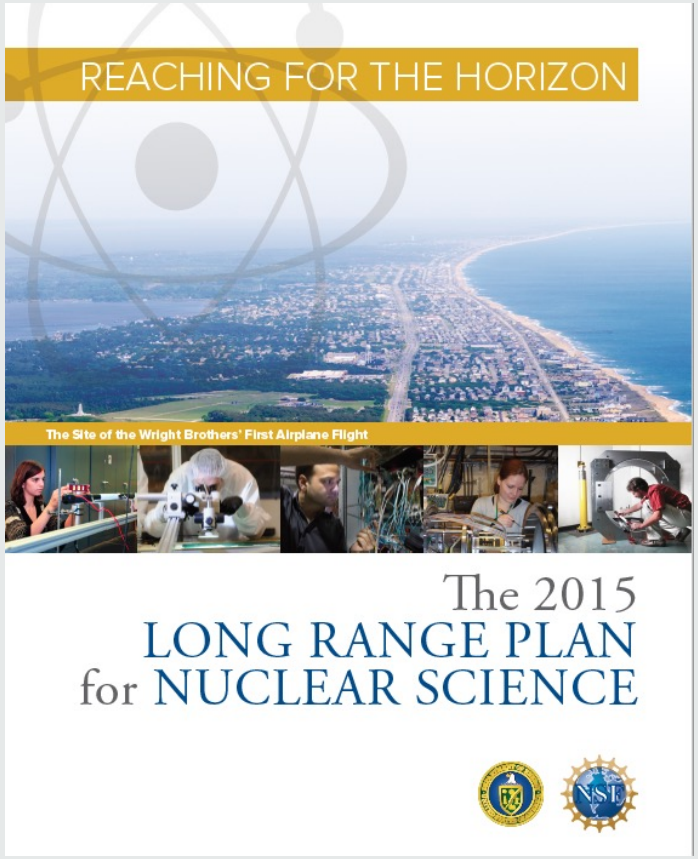
- Began with evolutionary upgrades of the CEBAF accelerator energy:
  - 4.0 GeV (spec) to 5.5 GeV (now)
  - on track for 6 GeV this year w/ January shutdown projects:
    - NL/SL cryomodule "shuffle"
    - 20th cryomodule added to SL
- Upgrade to 12 GeV, 100% DF (2001-07)
  - "Natural" extension, beautifully matched to the next generation of experiments
  - Excellent scientific justification (to be documented by the white paper developed following this workshop)

Workshop on Physics Opportunities with 12-GeV Electrons

Jefferson Lab, Newport News, Virginia
January 13-15, 2000

From 12 GeV to ~24 GeV cannot be anymore a "natural" extension

The Impact of EIC



RECOMMENDATION III

Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.

We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

Large overlap in science topics

- Nucleon Tomography
- Spectroscopy
- Nucleon& Nuclear PDFs
- Hadronization
- Saturation
- …

What is the crucial role that CEBAF can play in this panorama?

Uniqueness of CEBAF

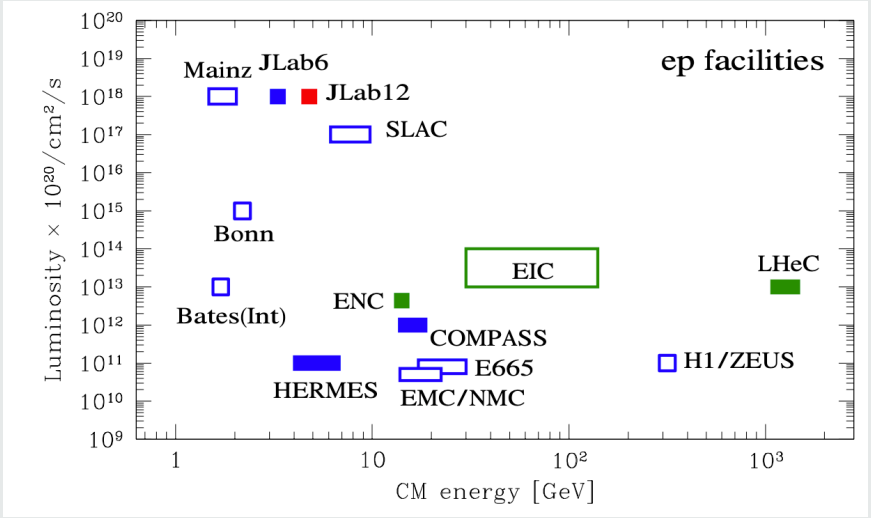
EIC vs CEBAF

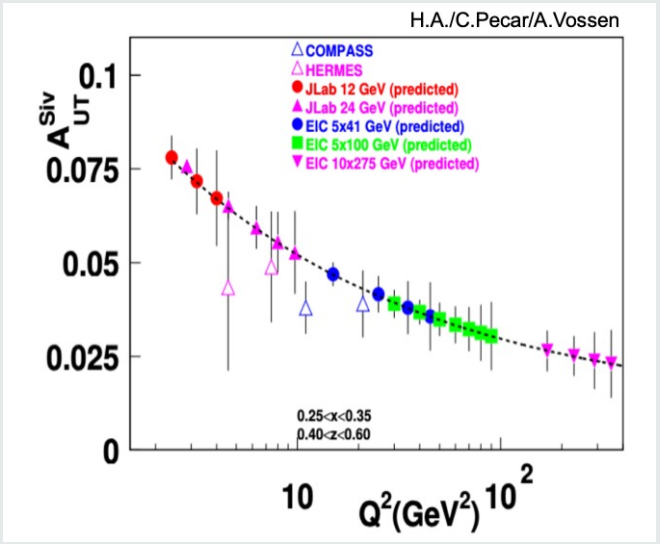
Gain ~30 in C.M. energy but 100,000 lower in luminosity → CEBAF will remain the prime facility for fixed target electron scattering at the luminosity frontier

- Precision measurements in the valence quark region at high luminosity with the 24 GeV upgrade will provide important extension into the sea quark region while the EIC is designed to probe mainly at low x.

- A photoproduction facility with a 24 GeV CEBAF will provide an opportunity to study XYZ exotic states in exclusive reactions at lower energies and with higher luminosity compared to EIC. It would be much more efficient and could provide much needed insights into the nature of these intriguing resonances.

- 24 GeV CEBAF provides significantly higher Q^2, low x values in the valence region which is critical for several key measurements.





- **Measurements of Q2-dependence of SSAs will be crucial in validation of the theory**
- **JLab24 will be crucial to bridge the TMD studies between JLab12 and EIC**

Some Questions to Answer

1. Are there key science questions accessible with E>20 GeV needed for advancing our insight into QCD?

2. Are there unique measurements that can be carried out at CEBAF to complement the EIC program? (maximum return on DOE investment)

3. Can we develop a compelling physics program that can be carried out "in stages" to avoid initial major detectors upgrade?

Plan Development for Higher Energy Upgrade

- Preparation of 1-d workshops series started
  - Organizers identified and invited
  - Development of the physics case requires substantial simulation work

- Workshops should be completed by summer 2022.

- For each topic write 1-2 pages to be collected in a white paper for presentation to a broader community. Science case should be clear and concise.

- Physics case reviewed by a Scientific Committee? (Special PAC 18 Review of the Science Driving the 12 GeV Upgrade -July 2000).

- Indication that the charge for the next LRP will be given to NSAC in June.

Conclusions

- CEBAF is and will remain the prime facility for fixed target electron scattering at very high luminosity.
- We need to expand the time horizon of Jlab's scientific program beyond 2030. Ideas have been developing on extending CEBAF energy, luminosity and accelerating positrons.
- We are preparing to make the case for the next Long Range Plan for Nuclear Physics. A strong physics program has to be developed showing that :
    - The research is unique to CEBAF and will not be possible – or will be very challenging - at any other know facility in the foreseeable future.
    - The scientific opportunity afforded by the upgrades is outstanding, providing the U.S. with unique world-leadership capabilities in studies of QCD and the quarks and gluon structure of matter.
    - The research is needed to complement the EIC program.
- We have to face a strong competition within the NP community and therefore we have to be able to articulate our message strongly and clearly.