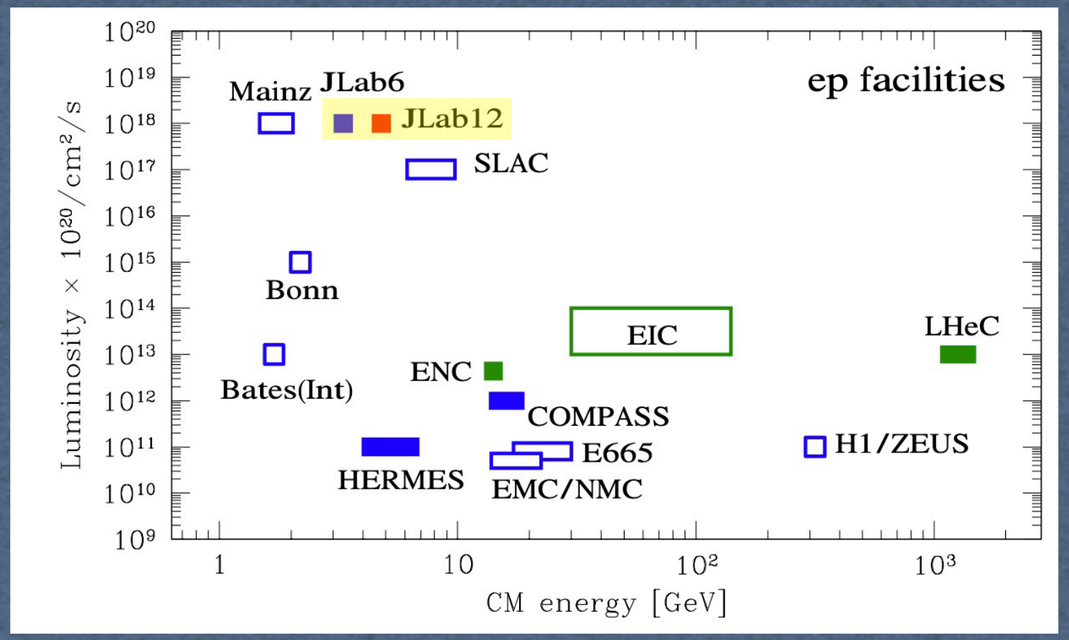
QNP2022 - The 9th International Conference on Quarks and Nuclear Physics

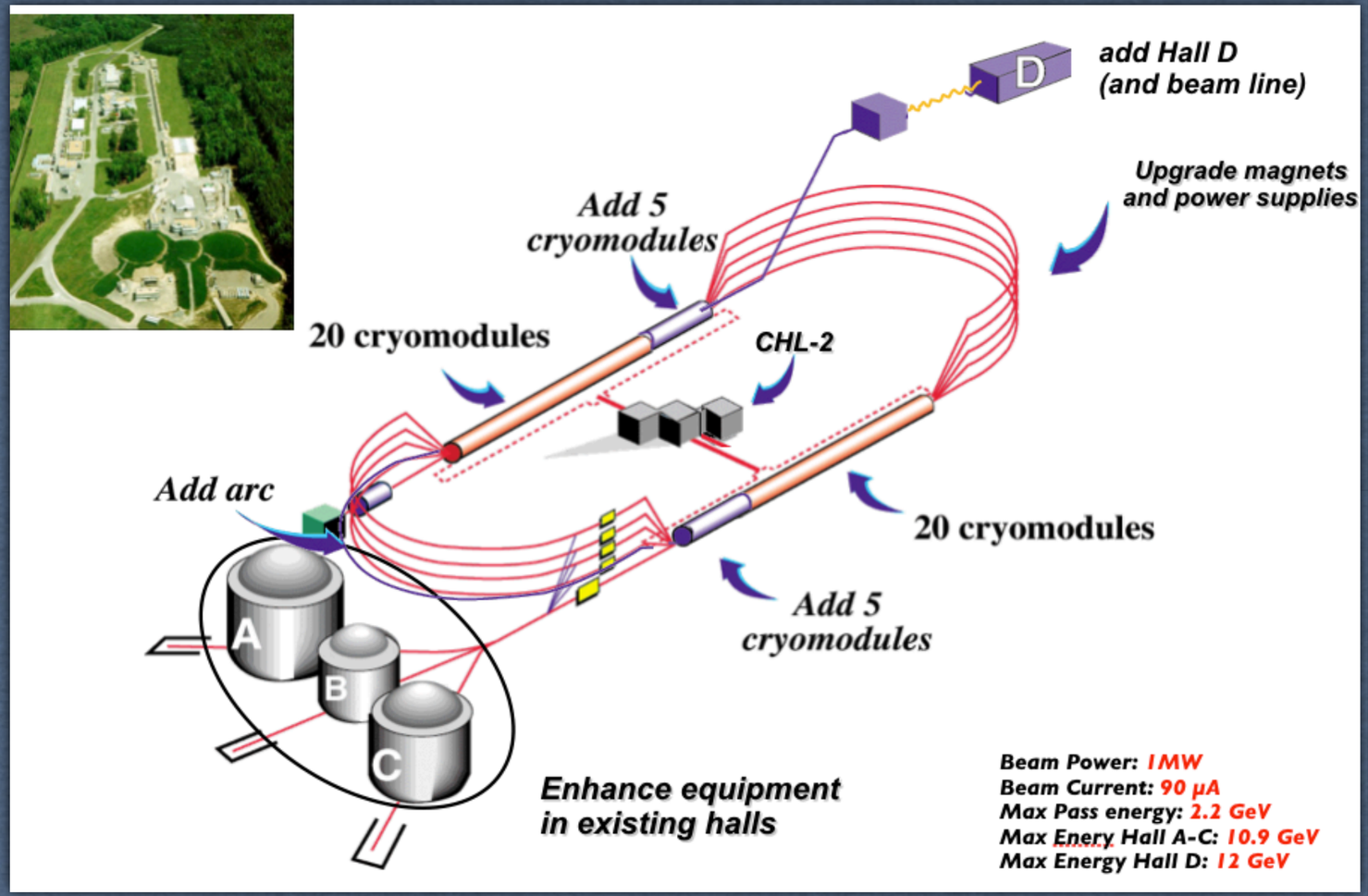
5-9 September 2022

Future Physics Opportunities at Jefferson Lab

M.Battaglieri (INFN)

Jefferson Lab

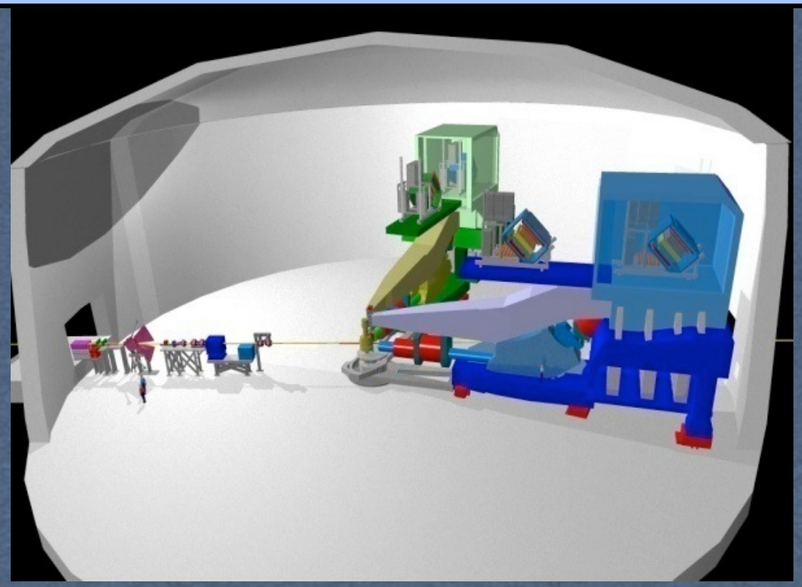




- ✳Primary Beam: Electrons
- ✳ Beam Energy: 12 GeV
  - 10 > λ > 0.1 fm
  - nucleon → quark transition
  - baryon and meson excited states
- ✳100% Duty Factor (cw) Beam
  - coincidence experiments
  - Four simultaneous beams
  - Independent E and I
- ✳ Polarization
  - spin degrees of freedom
  - weak neutral currents

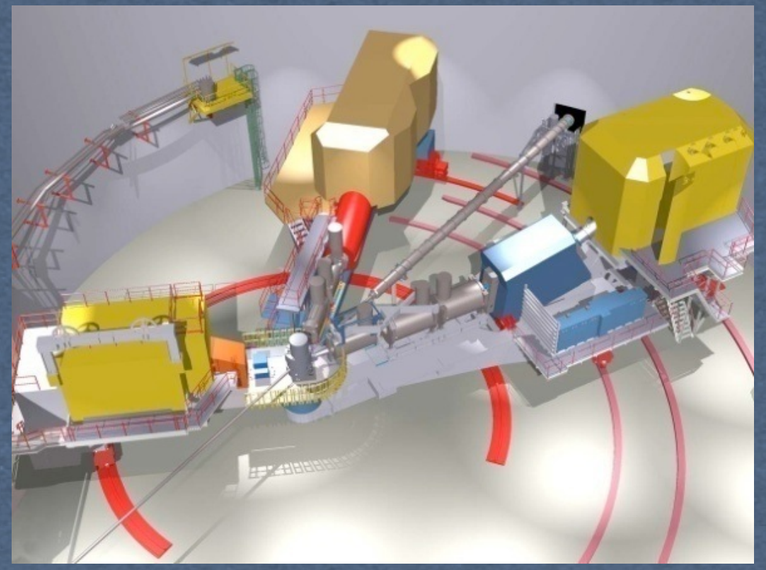
Luminosity > 10^7 -10^8 x SLAC at the time of the original DIS experiments!

12 GeV equipment



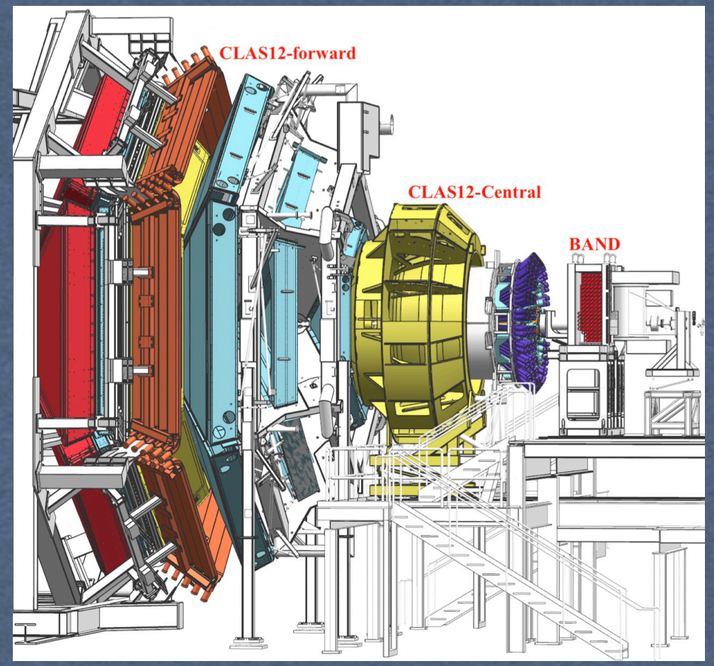
Hall A – High Resolution Spectrometers and new multipurpose large acceptance detectors

✳ short range correlations, form factors, and future new experiments: SOLID, MOELLER, SBS



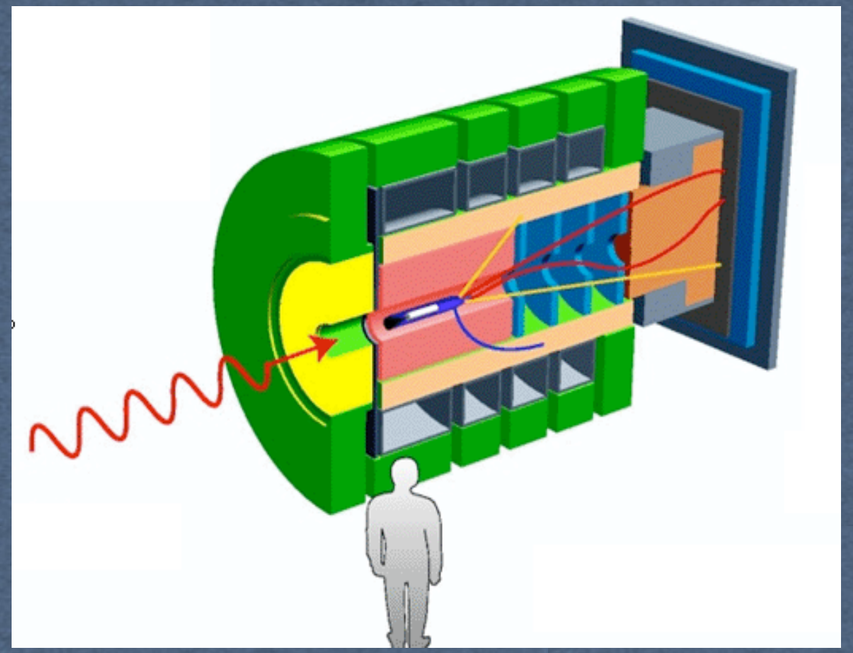
Hall C – Super High Momentum Spectrometer (SHMS)

✳ precise determination of valence q properties in nucleons and nuclei



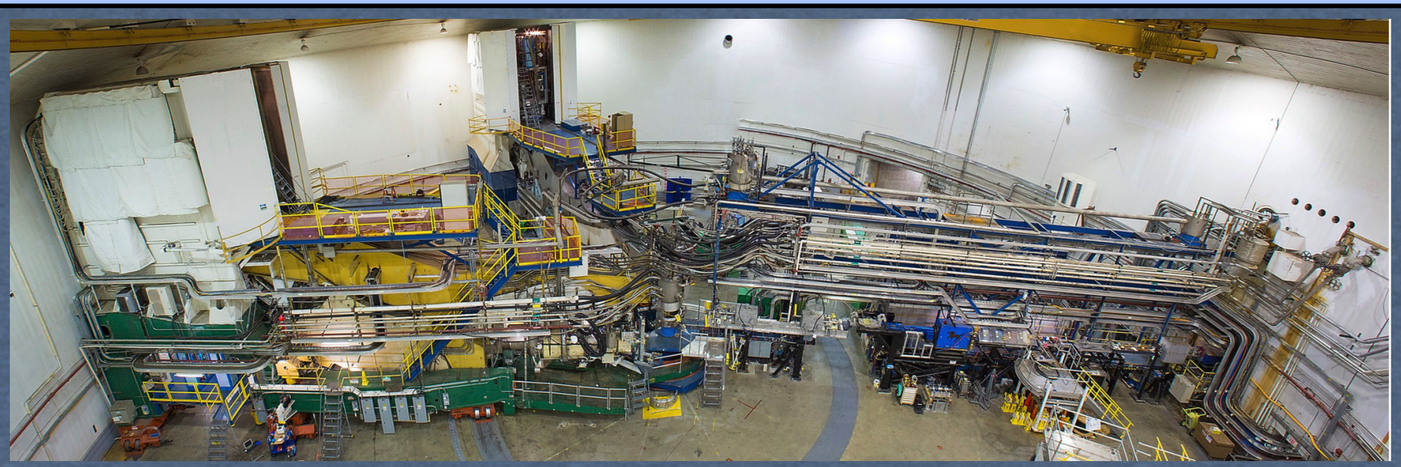
Hall D – GLUEx detector forphotoproduction experiments

✳ explore origin of confinement by studying hybrid mesons

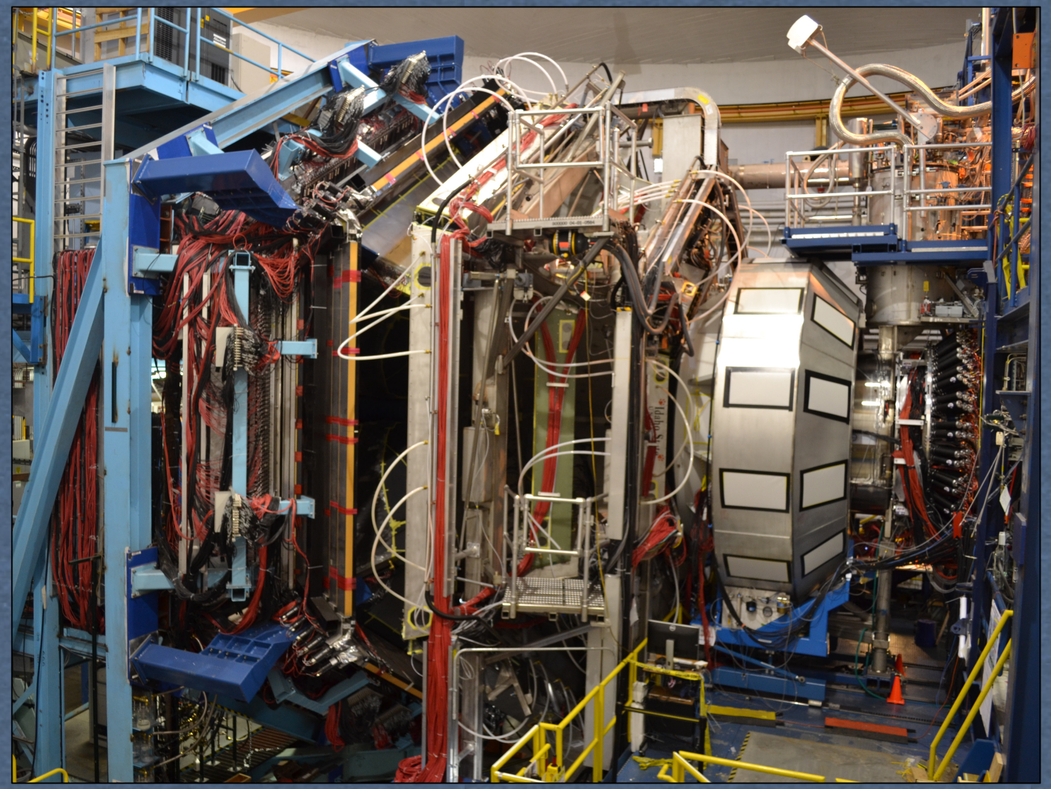


Hall B – Large acceptance detector CLAS12 for high luminosity measurements ($10^{35}cm^{-2}s^{-1}$)

✳ Understanding nucleon structure via GPDs and TMDs and hadron spectroscopy

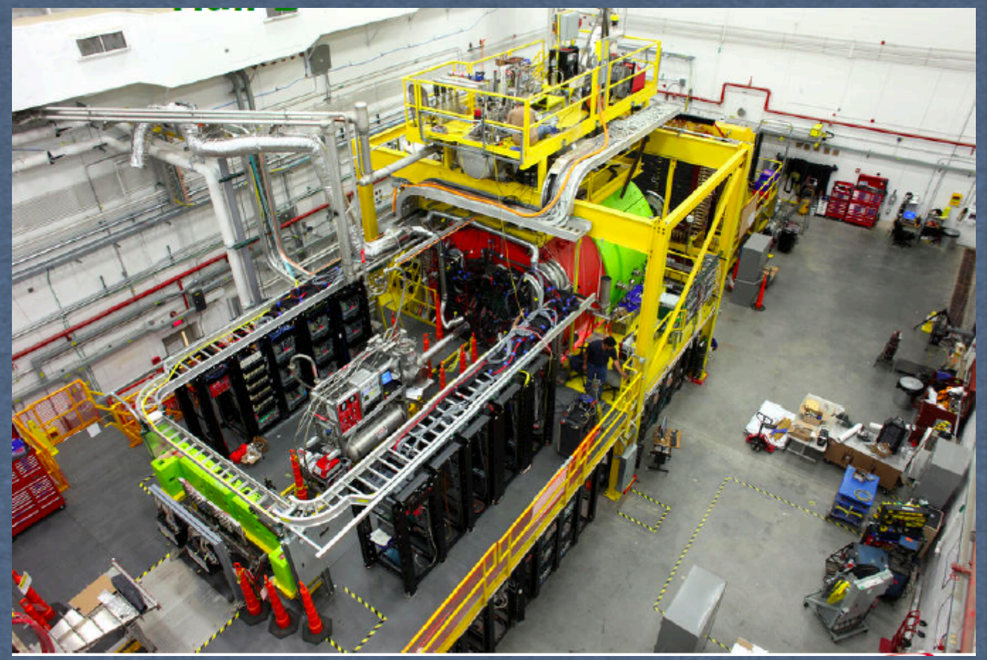


Hall A



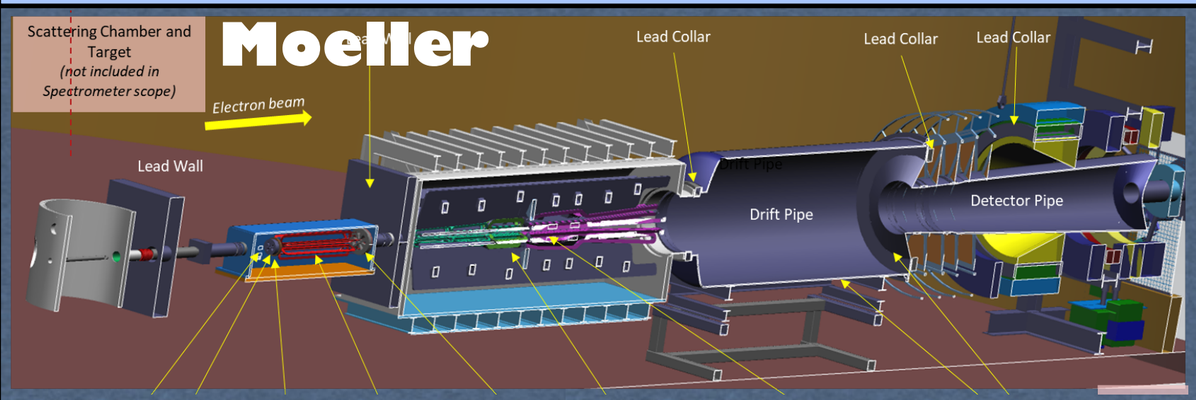
Hall B

Hall C



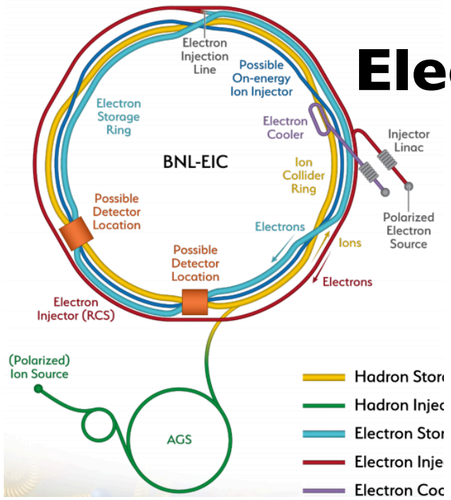
Hall D

Future (present) projects

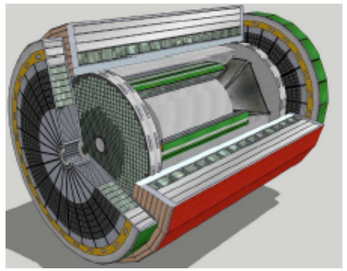


- Solenoidal Large Intensity Device – new multipurpose detector facility optimized for high luminosity and large acceptance, enabling very broad scientific program
- Unique capability combining high luminosity ($10^{37\text{-}39}$ /cm2/s) (more than 1000 times the EIC) and large acceptance, with full ϕ coverage to maximize the science return of the 12-GeV CEBAF upgrade

EIC
Electron Ion Collider



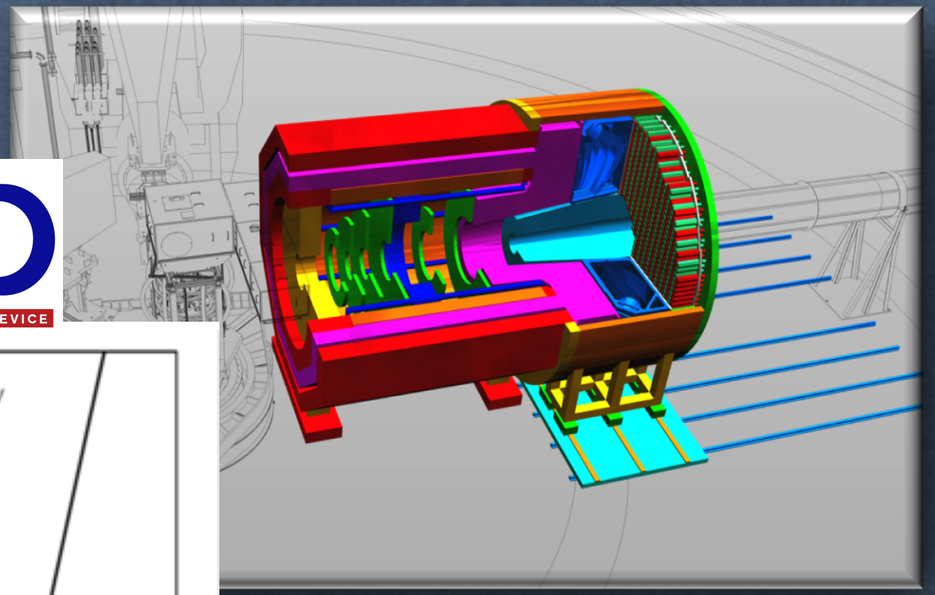
- Luminosity 100-1000 times that of HERA
- Polarized protons and light nuclear beams
- Nuclear beams of all A (p→U)
- Center mass variability with minimal loss of luminosity

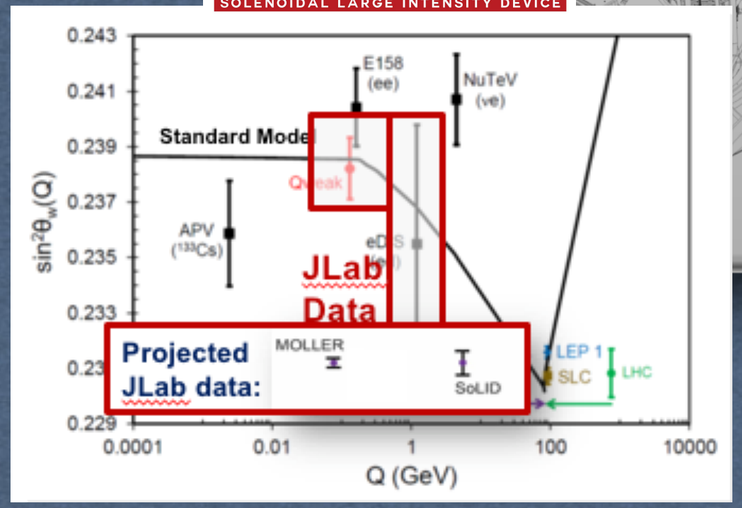


ePIC detector

- Large acceptance
- Frwrd/Bckw angles
- Precise vertexing
- HRes Tracking
- Excellent PID

SoLID
SOLENOIDAL LARGE INTENSITY DEVICE

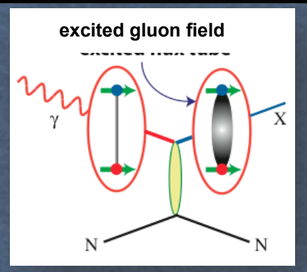




- Unique discovery space for new physics up to 38 TeV mass scale, with a purely leptonic probe
- CD-0 approved 2017, ready for CD-1

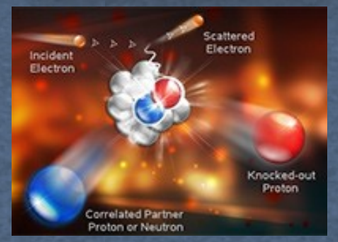
JLab Scientific mission

- What is the role of gluonic excitations in the spectroscopy of light mesons?
- Where is the missing spin in the nucleon? Role of orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through 3D imaging at the femtometer scale?
- What is the relation between short-range N-N correlations, the partonic structure of nuclei, and the nature of the nuclear force?
- Can we discover evidence for physics beyond the standard model of particle physics?



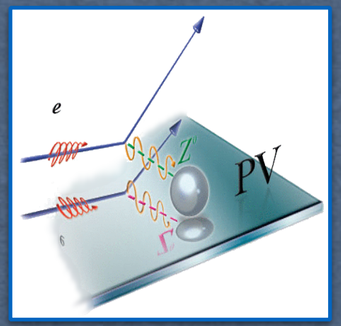
12 GeV experimental program is in full swing

- 33 experiments completed out of 91 approved
- ~8 years of physics ahead (~30 weeks/year)



Future opportunities at CEBAF

- Higher Energy
- Higher luminosity
- Positron beam



Physics with CEBAF at 12 GeV and Future Opportunities

J. Arrington[1], M. Battaglieri[2,15], A. Boehnlein[2], S.A. Bogacz[2], W.K. Brooks[10], 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[2,8], P. Rossi[2,14], M. Schram[2], S. Stepanyan[2], J. Stevens[8], A.P. Szczepaniak[12,13,2], N. Toro[9], X. Zheng[11]

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Abstract

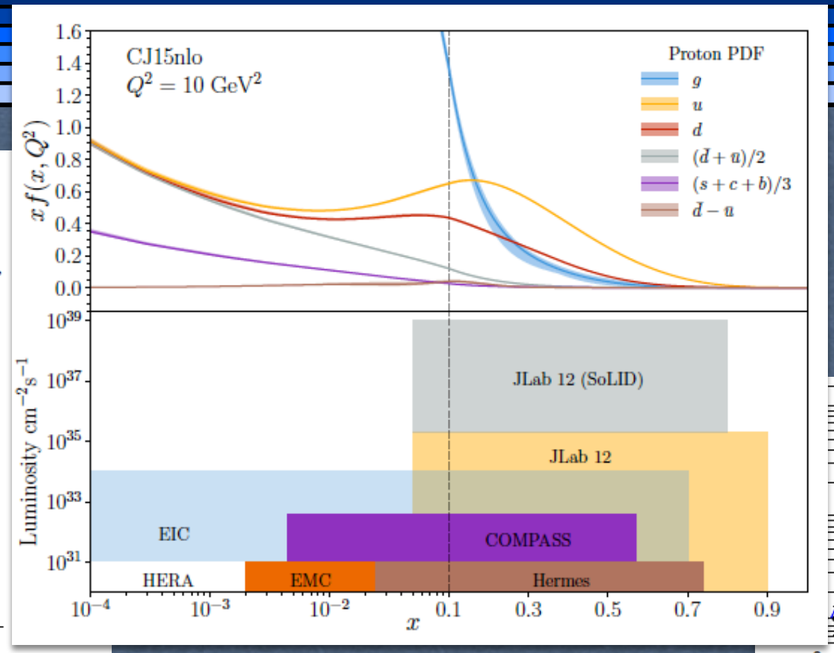
We summarize the ongoing scientific program of the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) and give an outlook into future scientific opportunities. The program addresses important topics in nuclear, hadronic, and electroweak physics including nuclear femtography, meson and baryon spectroscopy, quarks and gluons in nuclei, precision tests of the standard model, and dark sector searches. Potential upgrades of CEBAF are considered, such as higher luminosity, polarized and unpolarized positron beams, and doubling the beam energy.

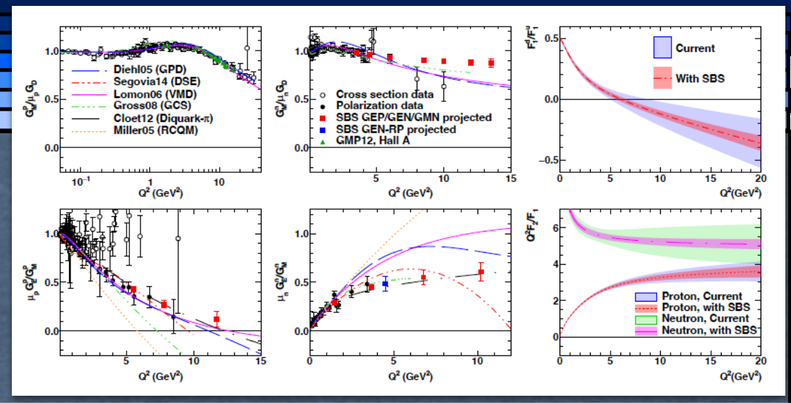
Keywords:

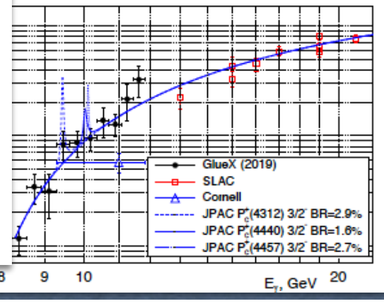
Contents

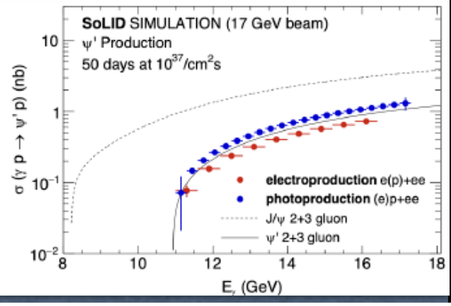
*Corresponding author, *email address:* bmck@jlab.org

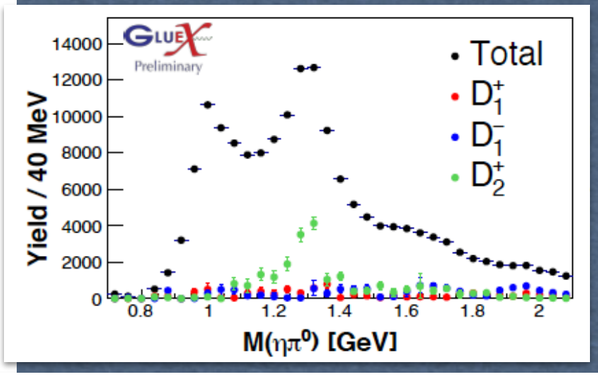
Preprint submitted to Progress in Particle and Nuclear Physics *December 2, 2021*

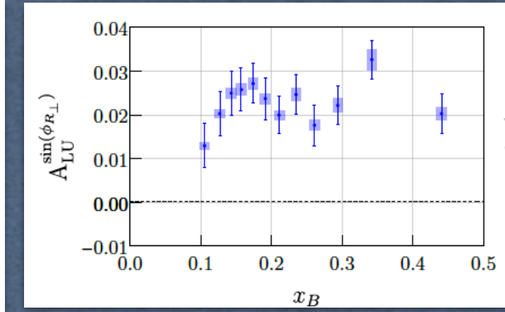


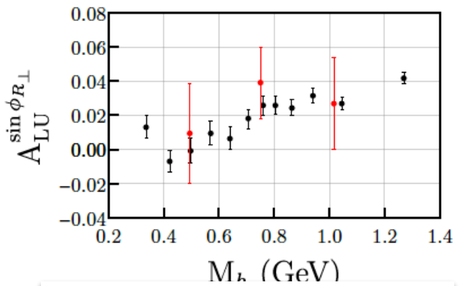


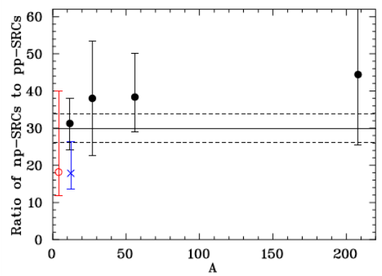


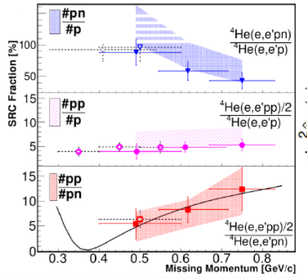


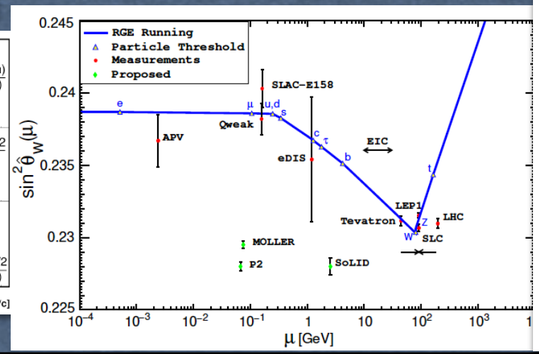


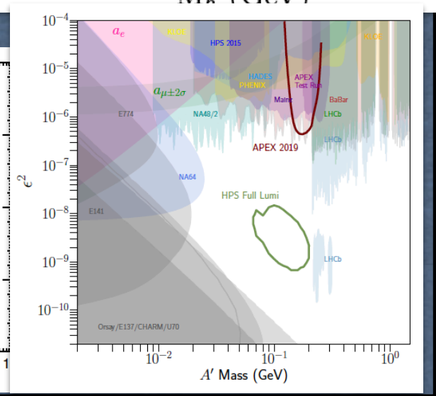












- **JEFFERSON LAB leadership and the USERS community are discussing a possible upgrade of future operations**
  - *Physics with CEBAF at 12 GeV and Future Opportunities:* a white paper submitted to Progress in Particles and Nuclear Physics Physics
  - Users-organized workshops (J-Future (Italy), APCTP (S. Korea), ECT* (Italy)
  - High Energy workshop series

J-FUTURE

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

TOPICS

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

ORGANIZERS

M. Battaglieri (INFN Genova)
G. Mandaglio (Messina U. and INFN Catania)
A. Pilloni (Messina U. and INFN Catania)
A. Szczepaniak (Indiana U. and JLab)
E. Voutier (LPSC Grenoble)

WORKSHOP SECRETARY

ABSTRACT

While the JLab 12 GeV program is running, time to plan the future developments for t

A new round of upgrades to CEBAF are unc development. One of these is a potential e to 24 GeV using novel magnet designs in t recirculation arcs. Another is a potential fo polarized beams of electrons or positrons, allow for new measurements in nucleon to provide precision extraction of contribution order electromagnetic currents, and allow the standard model. In addition, it is possib research lines using secondary beams.

The workshop will gather theorists and exp to discuss the physics opportunities for ea scenarios.

Physics with CEBAF at 12 GeV and Future Opportunities

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, Sezione di Genova, 16146 Genov

um of the 12 GeV Continuo
tific opportunities. The pro
; nuclear femtography, mesc
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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

Overview
Call for Abstracts
Timetable
Contribution List
Registration
Participant List
Invited Speakers
Transportation
Regarding COVID-19 & Visa (updated at May)

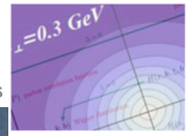
The electroproduction of mesons and photons has been shown to be a powerful tool for studies of the interaction of elementary particles and their dynamics at short and long distances. In particular, studies of the orbital motion of partons encoded in transverse space and momentum distributions of partons, 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 $N \to N^*$ (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

HIGH ENERGY WORKSHOP SERIES 2022

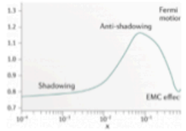
We are pleased to announce an upcoming series of summer workshops being organized jointly between the laboratory and the Jefferson Lab Users Organization (JLUO) to probe the science that would be opened up by a higher energy electron beam (~20-24 GeV) at Jefferson Lab. We are particularly interested in identifying key measurements that are not possible to access at 12 GeV, that initially utilize largely existing or already-planned Hall equipment, and that leverage the unique capabilities of luminosity and precision possible at Jefferson Lab in the EIC era.

Organizing Committee:

Ed Brash, JLUO Chair - David Dean - Carlos



The Next Generation of 3D Imaging
July 7
Harut Avagyan, Carlos Munoz Camacho, Jian-Ping Chen, Xiangdong Ji, Jianwei Qiu, Patrizia Rossi



Science at Mid x: Anti-shadowing and the Role of the Sea
July 22,23
John Arrington, Mark Dalton, Thia Keppel, Wally Melnitchouk, Jianwei Qiu

Physics Beyond the Standard Model
August 1
Marco Battaglieri, Bob McKeown, Xiaochao Zheng

J/Psi and Beyond
August 17
Ed Brash, Ian Cloet, Zein-Eddine Meziani, Jianwei Qiu

OPPORTUNITIES WITH JLAB ENERGY AND LUMINOSITY UPGRADE

26 September 2022 — 30 September 2022

ECT* - Villa Tambosi
Strada delle Tabarelle, 286
Trento - Italy

Show map Get directions

The Jefferson Lab upgraded to 24~GeV, will supersede HERMES, which even after being closed already 10 years still defines the landscape of the nucleon 3D structure, collecting years of HERMES data in days. Energy upgrade of JLab will provide access to the full range of kinematics where the non-perturbative sea is expected to be significant, also opening up the phase space to access large momentum transfer and large transverse momenta of final state particles. In addition, near-threshold charmonium photoproduction will enable studies of the gluonic properties of the proton, and an extensive program at the intensity frontier will cover light and heavy quark hadron spectroscopy in a single experiment. The possibility of a positron beam with the same properties and qualities as the electron beam will be a tremendous benefit for the physics program and the production of secondary beams at JLab, for instance, K_S-long beams will also benefit enormously from the energy upgrade, providing access to much wider kinematic domains.

ECT*
EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS
FONDAZIONE BRUNO KESSLER

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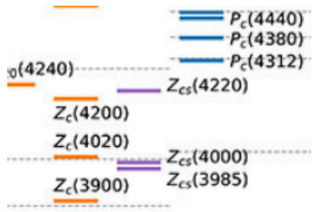
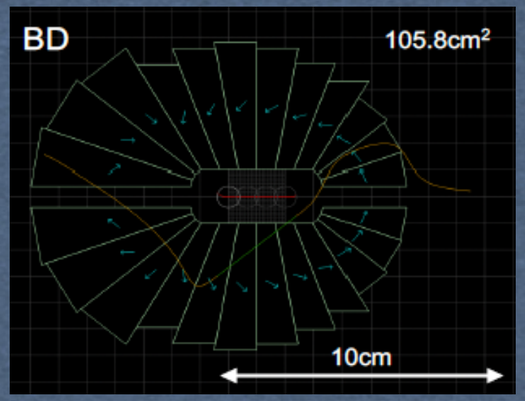


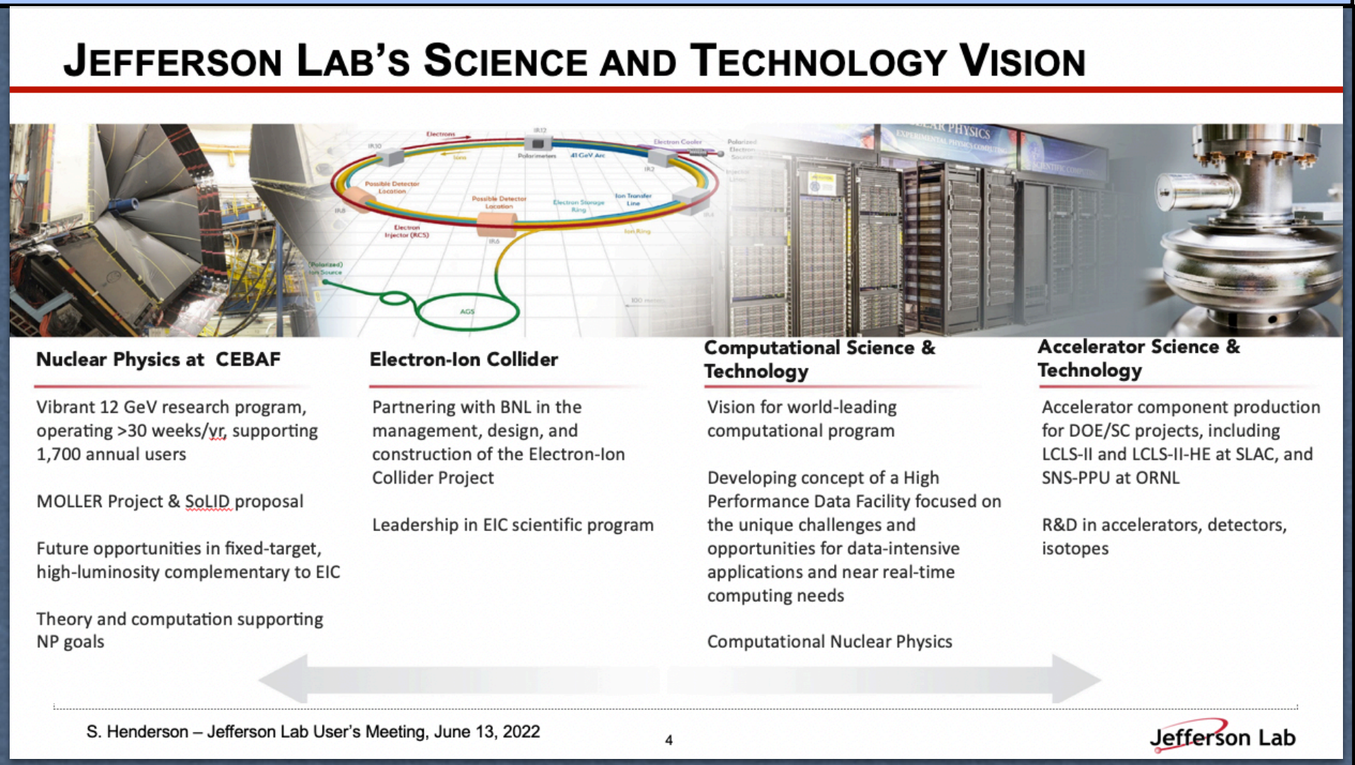
Hadron Spectroscopy with a CEBAF Energy Upgrade
June 16 & 17
Marco Battaglieri, Sean Dobbs, Derek Glazier, Alessandro Pilloni, Justin Stevens, Adam Szczepaniak

Recent observations in heavy-quark spectroscopy have provided numerous candidates for hadronic resonances which are exotic in nature, the so-called XYZ and Pc states. With a CEBAF energy upgrade to 20-24 GeV these states and other charmonia may be studied in photoproduction and electroproduction measurements at JLab. This workshop aims to identify the key measurements made possible by such an upgrade, utilizing recent theoretical models for production and evaluating the detector performance requirements.

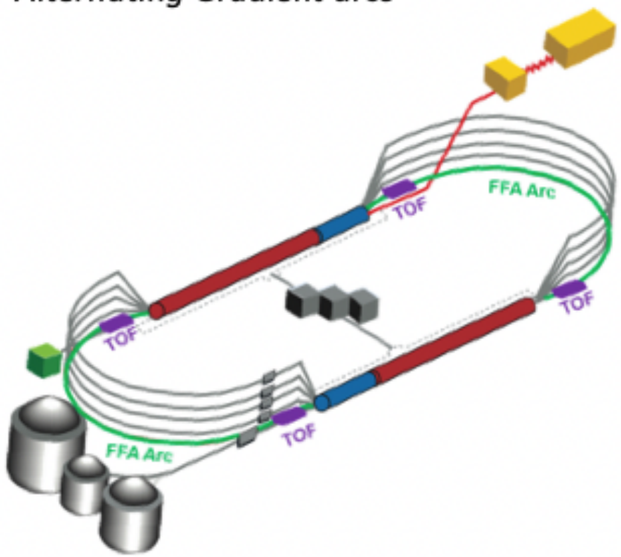
JLab upgrades: the context

- Lab leadership point of view
- Four pillars: NP, EIC, Data science, Acc. science
- 12 GeV program as the highest priority (but also positron beam and hi-lumi ops)
- CEBAF will remain the prime facility for fixed target electron scattering at hi-lumi
- JLab timeline: +2030!





Cost-effective path to doubling CEBAF energy based on Fixed-Field Alternating Gradient arcs



CEBAF at 22-23 GeV

- FFA recirculation technique (proposed for eRHIC): multiple beam energies confined and recirculated in the same beamline
- No new SRF (1.1 GeV per LINAC), replace the highest recirculation passes with two pairs of FFA arc
- 11 passes to reach 23 GeV
- High energy beam delivered to Hall-D and Hall B suitable for an HS physics program
- Hi-Lumi operations are not an issue

A.Bogacz

Higher Energy

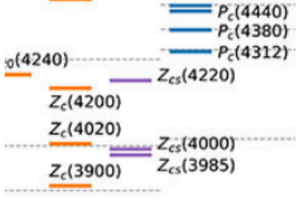
https://www.jlab.org/conference/hews22#

HIGH ENERGY WORKSHOP SERIES 2022

We are pleased to announce an upcoming series of summer workshops being organized jointly between the laboratory and the Jefferson Lab Users Organization (JLUO) to probe the science that would be opened up by a higher energy electron beam (~20-24 GeV) at Jefferson Lab. We are particularly interested in identifying key measurements that are not possible to access at 12 GeV, that initially utilize largely existing or already-planned Hall equipment, and that leverage the unique capabilities of luminosity and precision possible at Jefferson Lab in the EIC era.

Organizing Committee:

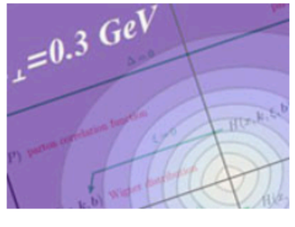
Ed Brash, JLUO Chair - David Dean - Carlos Munoz Camacho - Thia Keppel - Bob McKeown - Kent Paschke - Jianwei Qiu - Patrizia Rossi - Justin Stevens



Hadron Spectroscopy with a CEBAF Energy Upgrade

June 16 & 17

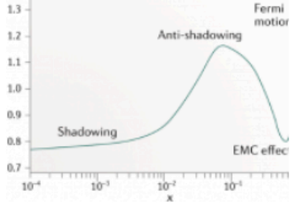
Marco Battaglieri, Sean Dobbs, Derek Glazier, Alessandro Pilloni, Justin Stevens, Adam Szczepaniak



The Next Generation of 3D Imaging

July 7

Harut Avagyan, Carlos Munoz Camacho, Jian-Ping Chen, Xiangdong Ji, Jianwei Qiu, Patrizia Rossi



Science at Mid x: Anti-shadowing and the Role of the Sea

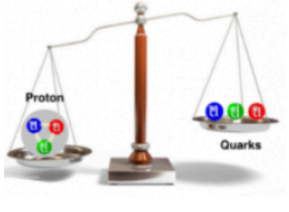
July 22,23

John Arrington, Mark Dalton, Thia Keppel, Wally Melnitchouk, Jianwei Qiu

Physics Beyond the Standard Model

August 1

Marco Battaglieri, Bob McKeown, Xiaochao Zheng



J/Psi and Beyond

August 17

Ed Brash, Ian Cloet, Zein-Eddine Meziani, Jianwei Qiu

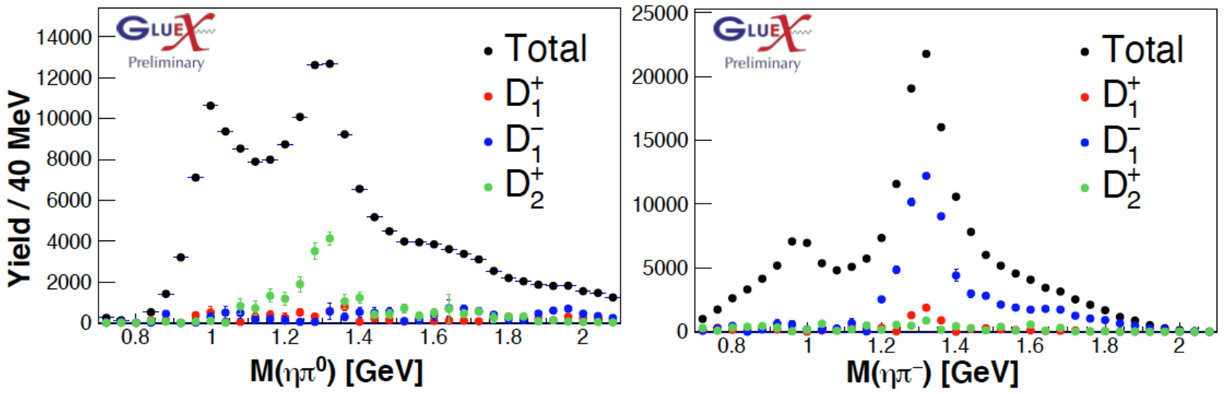
Measurements of J/psi near threshold with high statistics, for both electro and photoproduction at JLab with 12 GeV b
the community. A CEBAF energy increase (to ~24 GeV) will allow us to ask new questions and provide opportunities fo
nuclear and particle physics, thus enhancing the physics output of all four experimental halls, using existing (Halls B, C
equipment. This focused one-day workshop aims to **(1)** identify the key new measurements which could be made pos
specify the corresponding new questions that could be answered and the outstanding puzzles that could be addresse
Psi(2S) data near and above its threshold in exploring the size change of the probe through a comparison with the thre
enhanced Q lever-arm in J/psi electro-production that comes with higher energy beam, do we expect an improvemen
central to the origin of proton mass)? Does having the J/psi produced precisely, especially with 18-20 GeV beam, help

Hadron Spectroscopy with CEBAF@12 GeV: GLUEX

Exotic Meson Photoproduction

Hadron Spectroscopy

Primary goal for GlueX: Resonant (?) P-wave in $\vec{\gamma} p \to \eta\pi N$

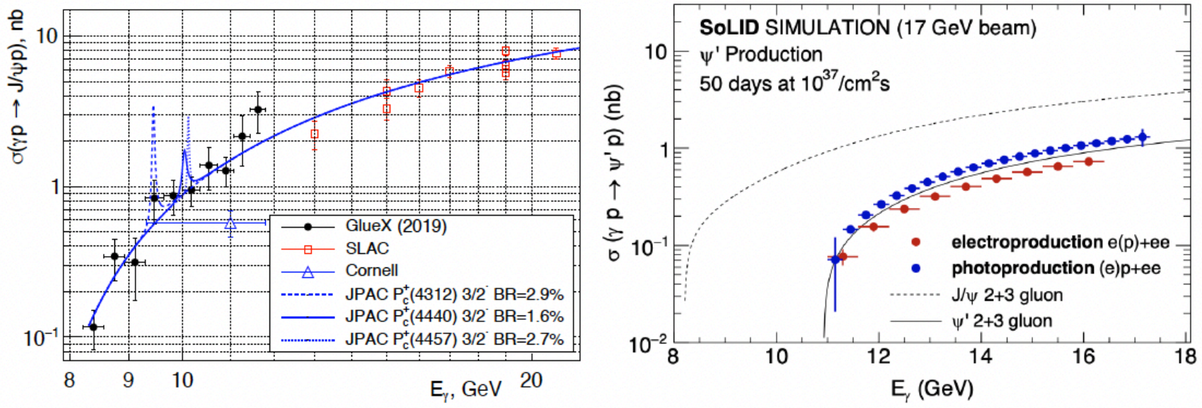


Excellent data quality, continuing analysis for unambiguous extraction of P-wave

Jim Napolitano 15 2022 JLUO Meeting

Photoproduction of J/ψ

Hadron Spectroscopy



- Searching for evidence of photproduction of pentaquark state
- Connection to proton mass radius: Phys Rev D 104(2021)054015

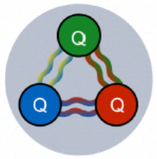
Jim Napolitano 16 2022 JLUO Meeting

- GLUEX experiment is the leaden meson spectroscopy program at 12 GeV
- First results available
- PWA to extract sub-leading waves in progress

J.Napolitano

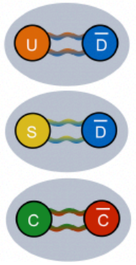
Hadron Spectroscopy: the physics case

Ordinary baryons:



proton	stable
neutron	$\tau \sim 10^3 s$
baryon Λ	$\tau \sim 10^{-10} s$

Ordinary mesons



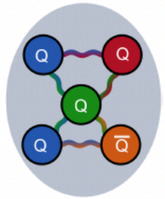
pion	$\tau \sim 10^{-8} s$
kaon	$\tau \sim 10^{-8} s$
J/ψ	$\tau \sim 10^{-20} s$

Exotic matter

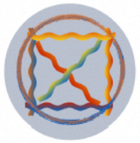
hybrid mesons

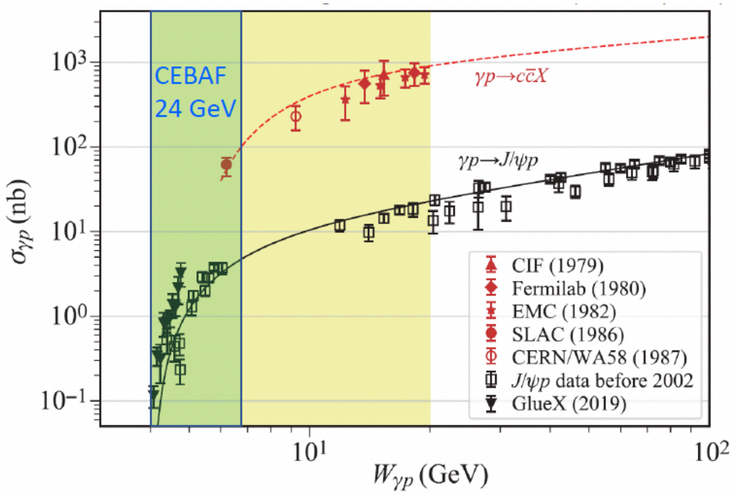
tetraquarks

pentaquarks



glueballs



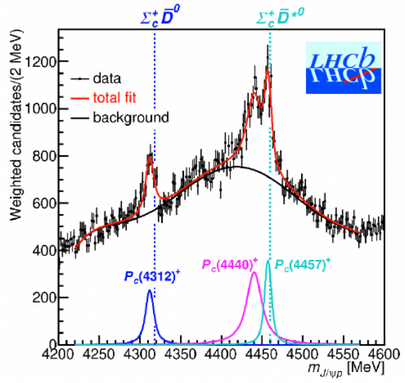


- The energy upgrade will provide the unique capability of covering light and charm q physics with the same machine
- Photoproduction is a preferred production mechanism to unravel the internal structure
- Photon polarisation is a key tool in disentangling production mechanisms
- Interpretation requires theory support
- Luminosity is an issue …

V.Mathieu, A.Szczpaniak, A.Pilloni, F.-K.Guo

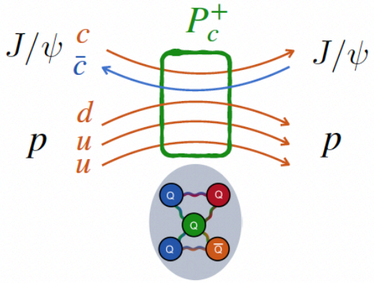
Pentaquarks candidates from LHCb

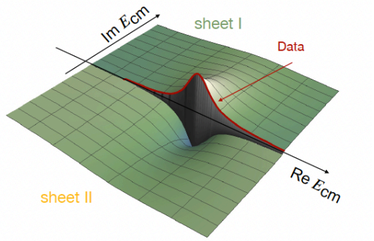
$\Lambda_b \to K^-(J/\psi\, p)$



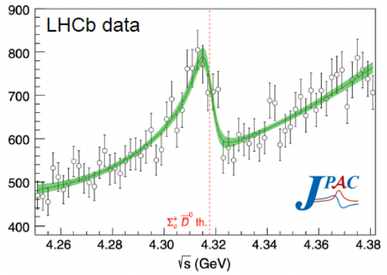
unexplained excess of events in $J/\psi\, p$ spectrum

Cannot be qqq baryon





Resonances are poles of the scattering amplitude

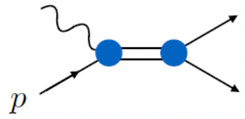


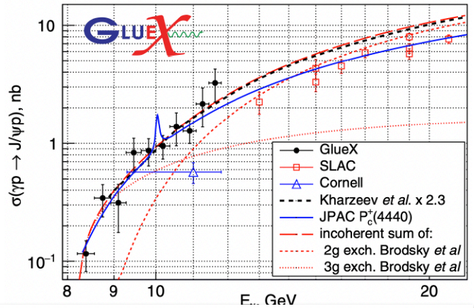
JPAC interpretation:

Virtual state in the $\Sigma_c^+ \bar{D}^0$ channel

Pentaquark @ JLab

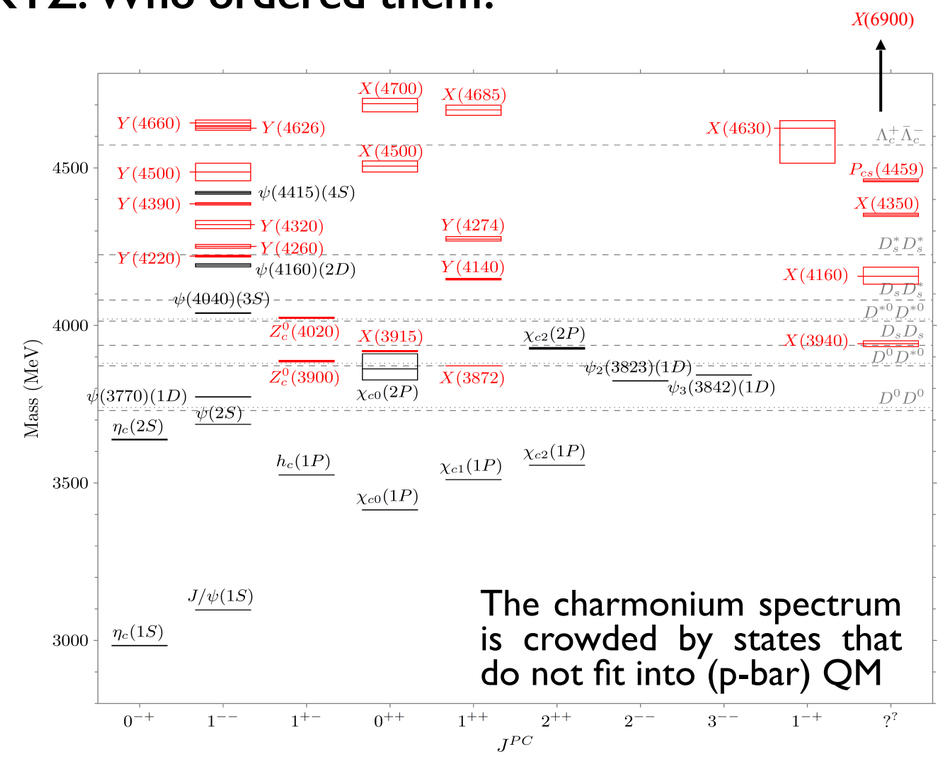
"direct" Photo-production of P_c^+





- Not surprising the GlueX observed no signal of P_c: $\sigma(\gamma p \to J/\psi p) = \mathcal{O}(1\ \text{nb}) \gg 10^2 \times \sigma(e^- p \to P_c + \text{anything})$, much higher statistics is needed

XYZ: Who ordered them?



The charmonium spectrum is crowded by states that do not fit into (p-bar) QM

$XYZP$ states have hadronic transitions to narrow charmonium states with surprisingly large rates

Some are explicitly 4-quark effects, *e.g.*, $Z_c^+(3900) \to J/\psi\pi^+$

- **54** observed exotics, both tetraquarks and pentaquarks
- A naïve count estimates well over 100 more exotics are waiting to be discovered
- Light q spectrum shows exotic candidates too: $\pi_1(1600)$, $f_0(1710)$, $\Phi(2170)$
- Little is know about the internal structure

The major experiments

Currently ongoing (with future upgrades approved or proposed), hadron spectroscopy is among major goals

- LHCb (CERN, E.U.) ✓
- Belle II (KEK, Japan) ✓
- BESIII (IHEP, China) ✓
- GlueX (JLab, U.S.) ✓

Currently running, hadron spectroscopy is a minor focus

- CMS (CERN, E.U.) ✓
- ATLAS (CERN, E.U.)

Future facilities

- Electron-Ion Collider [EIC] (approved: BNL, U.S.) ✓
- Super Tau-Charm Facility (proposed: China) ✓
- PANDA (planned: FAIR, Germany)
- JLab24 (proposed, U.S.) ✓

R.Lebed

Hadron Spectroscopy status

Modern Hadron Spectroscopy in the Snowmass 2021 Exercise

Summary of Topical Group RF07
(Rare Processes and Precision Measurements Frontier)

Richard Lebed, Arizona State University

Mesons depicted here, but each model has a baryonic analogue

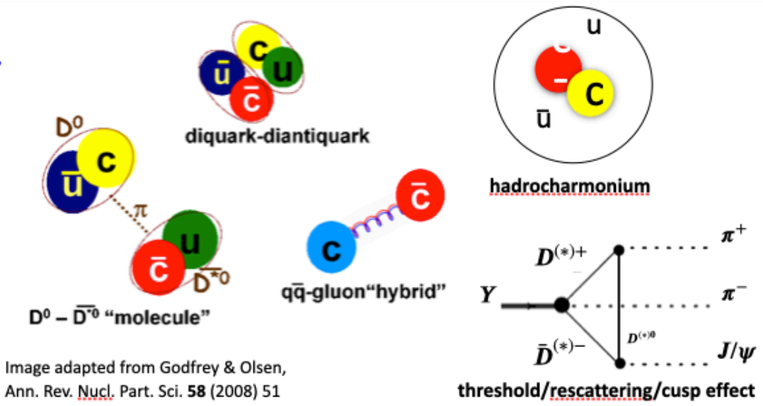
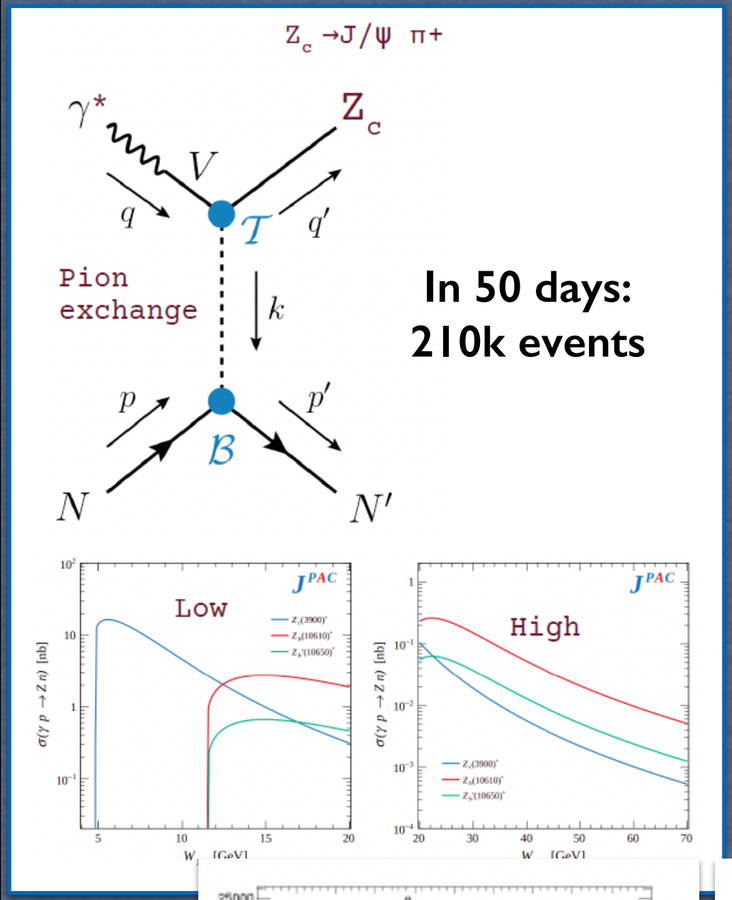


Image adapted from Godfrey & Olsen, Ann. Rev. Nucl. Part. Sci. **58** (2008) 51

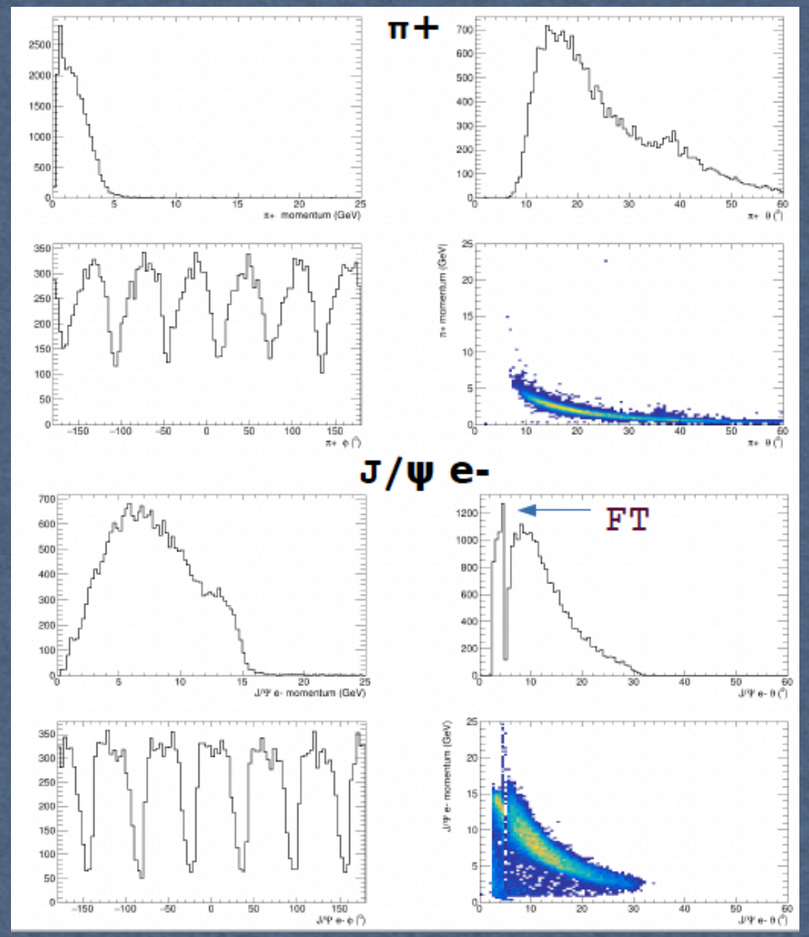
Recommendations from RF07

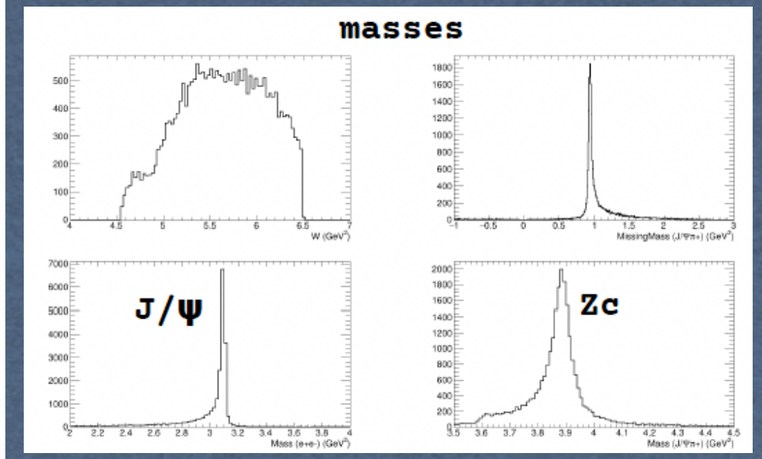
- Continued & expanded support for researchers at Belle II and BESIII: a big U.S. physics footprint for a small U.S. investment; training can be carried over to future Super Tau-Charm Facility
- U.S. facilities: support & training for junior researchers at GlueX, many of whom will then staff the upcoming EIC or possible JLab24
- Support for U.S. cross experiment/theory initiatives such as JPAC to carry out intricate multi-level amplitude analyses
- Support for U.S. multi-institution theory initiatives, including lattice, to broaden researchers' perspectives and generate new collaborations

$Z_c(3900)$ in CLAS24



In 50 days:
210k events

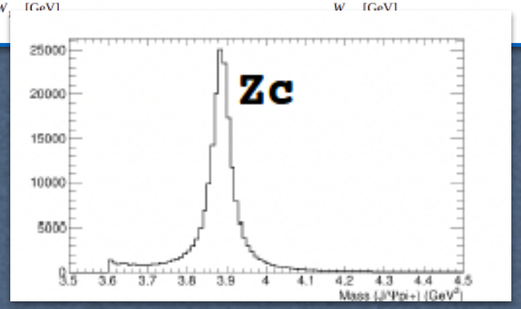


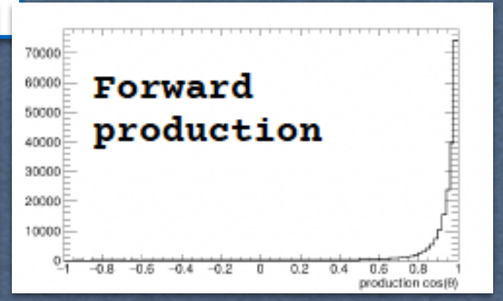


Similar exercise for:

- $\gamma\, p \rightarrow \Lambda\, Z_{CS}(4000) \rightarrow (p\, \pi^-)\, (J/\Psi\, K^+)$: 33k produced
- $\gamma\, p \rightarrow \Lambda_C\, D^0 \rightarrow (p\, \pi^-\, K^+)\, (\pi^-\, K^+)$: 450k produced
- To be folded in electron detection efficiency (min Θ_e)

meson	σ (nb)	total branch ratio	#/day
J/ψ	1.9	6%	21000
X(3872)	12	0.3%	3800
Y(4260)	0.7	0.06%	33
$Z_c(3900)$	5.1	0.6%	4200
$Z_{cs}(4000)$	1	0.4%	440
$D^0\Lambda_c$	100	0.25%	42000





- Overall acceptance ~12%
- ~25k Zc(3900) detected in 50 days

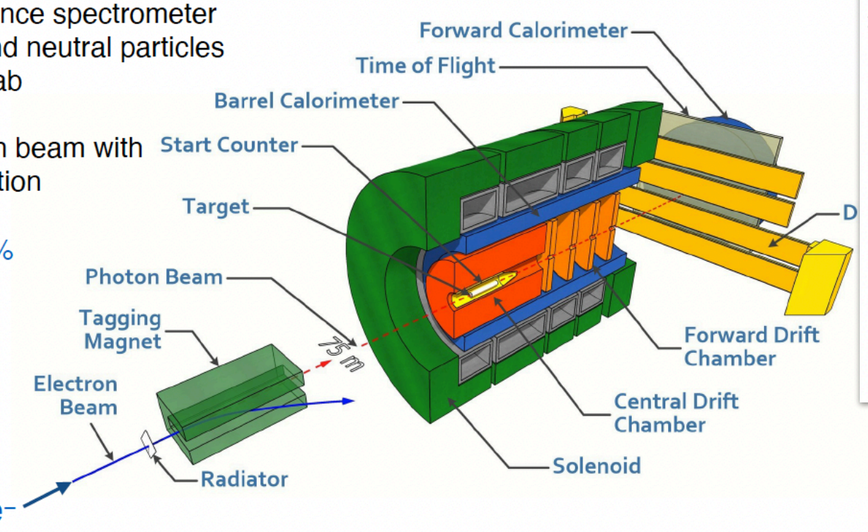
(assuming 5900 pb^{-1} corresponding to $L=10^{35}\ cm^{-2}\ s^{-1}$)

D.Glazier

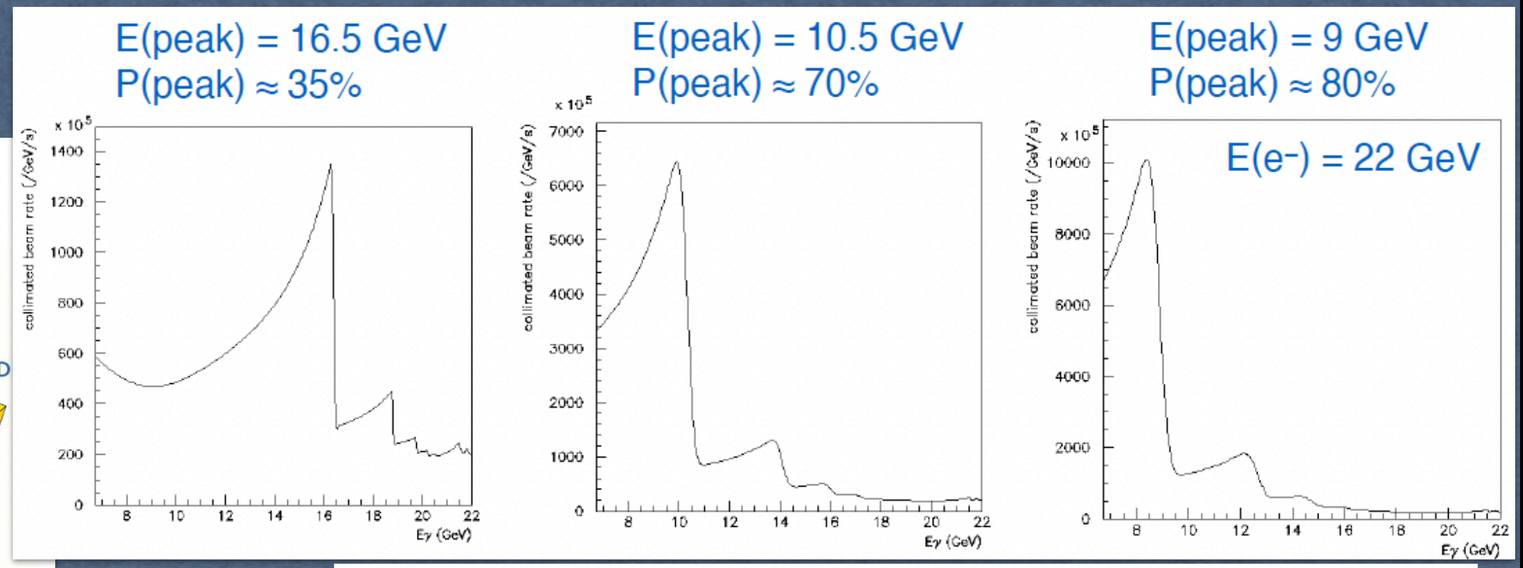
Heavy exotics with GLUEX

Large acceptance spectrometer for charged and neutral particles at Jefferson Lab

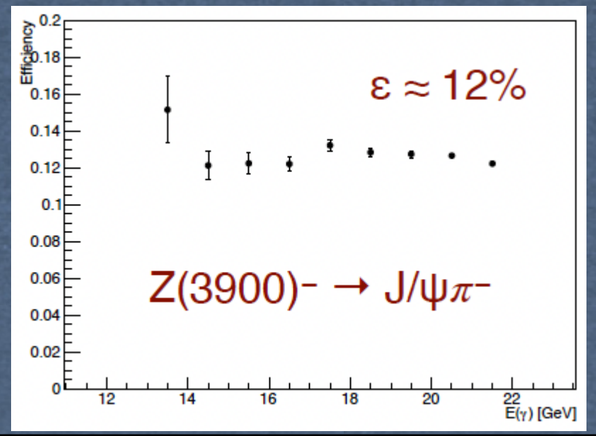
Tagged photon beam with linear polarization
P ~ 40%
σ(E)/E ~ 0.1%

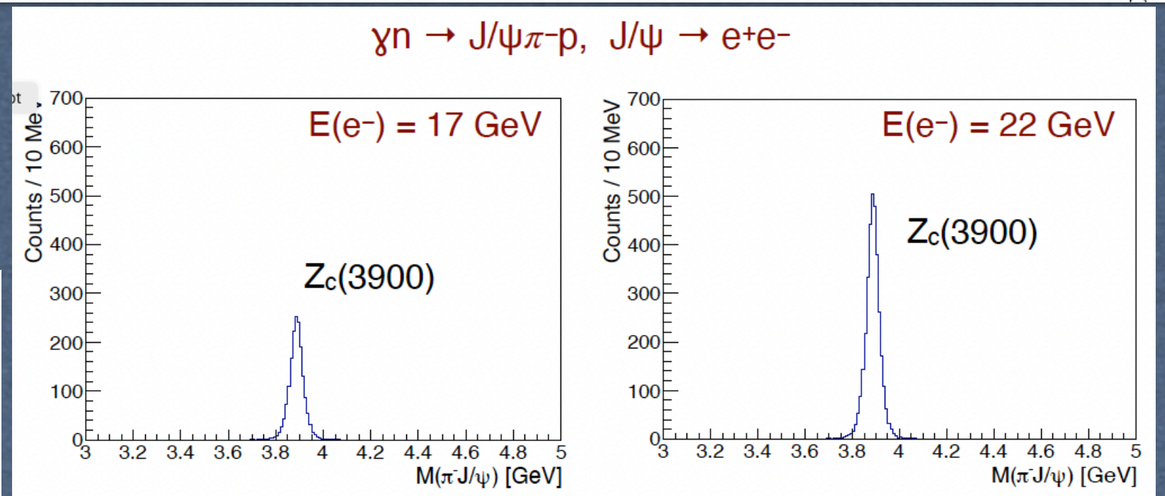


- Simulations performed with baseline GlueX-II spectrometer
- Assumes modest beam-line upgrades to handle higher energy electrons



- Ann extension of the current program seems to be possible
- Requires to detect large mom tracks
- effect on resolution and PID as well as efficiency





- Assumes 1 year @ 500 pb⁻¹, Br(Z⁻→ π⁻J/ψ) = 5%
- N(Zc(3900) J/ψπ⁻): 17 GeV = 1700, 22 GeV = 3400
- Uses JPAC prediction, assumes pure neutron target

S.Dobbs, J.Stevens

Physics opportunities: SIDIS/TMD

SIDIS @JLAB

- JLab12: a leading provider of information on 3D nucleon structure
  - Dihadron production: qualitatively new opportunities to study the non-perturbative QCD
  - Understanding the hadronization process
- Measurement of multiplicities and spin azimuthal asymmetries for all combinations of beam and target polarizations to access underlying TMDs

- Opportunities with 24 GeV
  - Enhancing the range in transverse momentum P_T of hadrons
  - Enhancing the Q^2 range
  - Enhancing the x-range

N/q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	h_1 $h_{1T}^\perp$

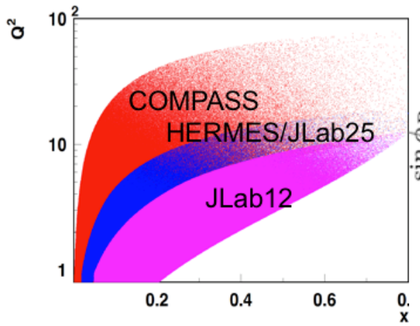
JLab 6 GeV to 12 GeV upgrade as an example

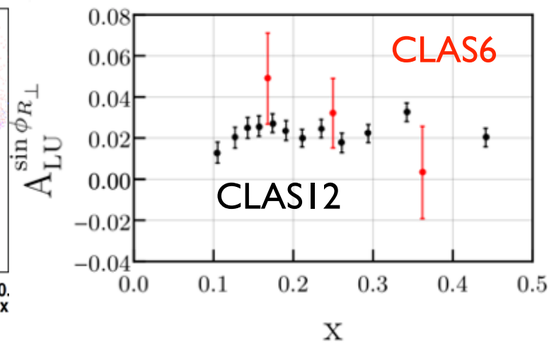
Observation of SSAs in ep→e'π⁺π⁻X

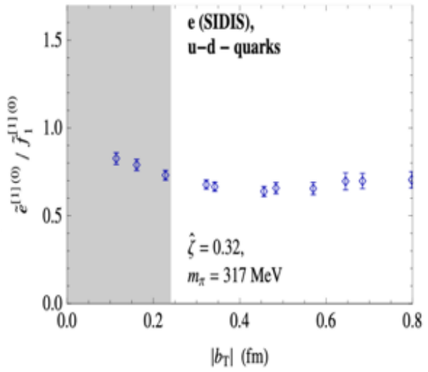
T. Hayward et al. Phys. Rev. Lett. 126, 152501 (2021)

$H_1^\sphericalangle =$

$$d\sigma_{LU} \propto \lambda_e \sin(\phi_{R\perp}) \left(x e(x) H_1^\sphericalangle(z, M_h) + \frac{1}{z} f_1(x) \tilde{G}^\sphericalangle(z, M_h) \right)$$





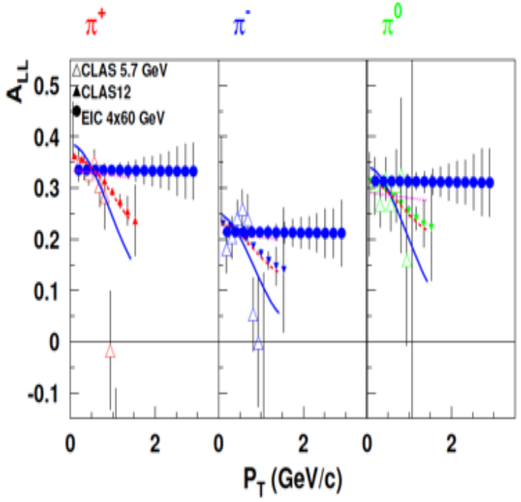


Doubling the JLab beam energy, opens the phase space for SIDIS dihadrons

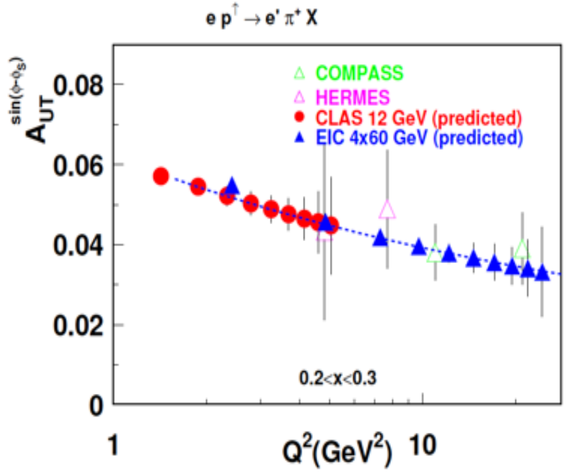
Quark gluon correlations may be very significant

CLAS12 kinematical coverage

k_T-dependence $g_1(x, k_T)$

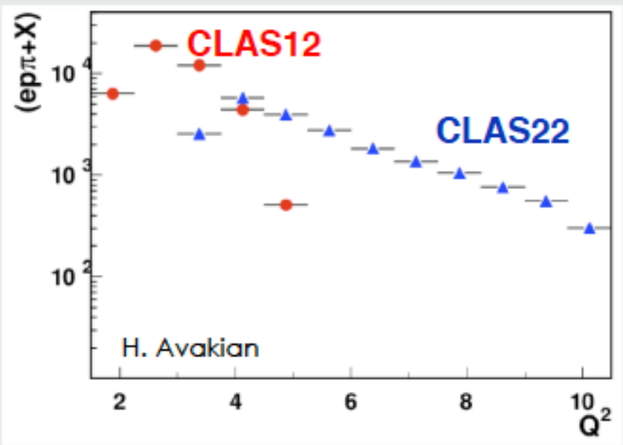


Q^2-dependence of Sivers $f_1^\perp(x, k_T)$

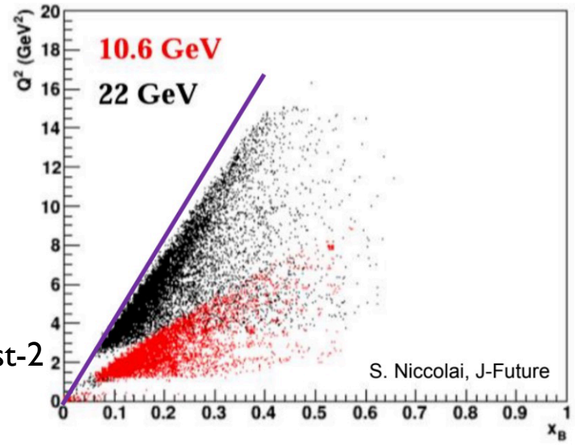


- Large acceptance of CLAS12 allows studies of P_T and Q^2-dependence of SSAs in a wide kinematic range (most critical for TMD studies)
- Comparison of JLab12 data with HERMES, COMPASS and EIC will pin down transverse momentum dependence and the non-trivial Q^2 evolution of TMD PDFs in general, and Sivers function in particular.

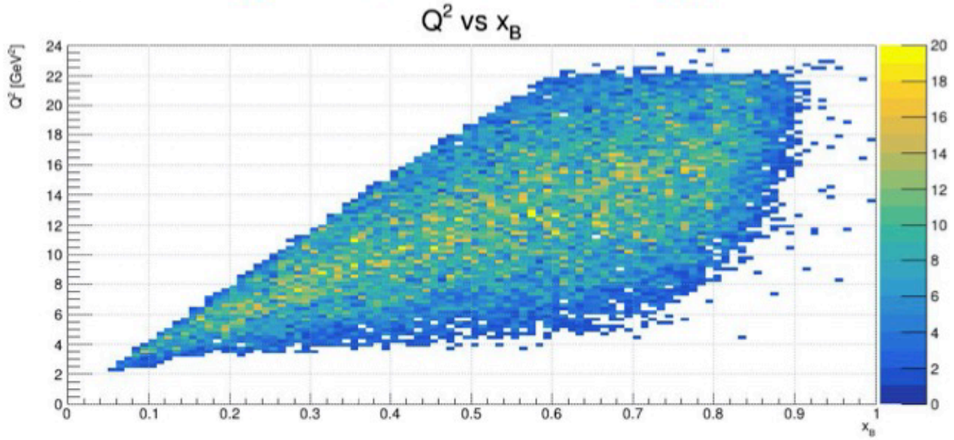
Physics opportunities: SIDIS/TMD

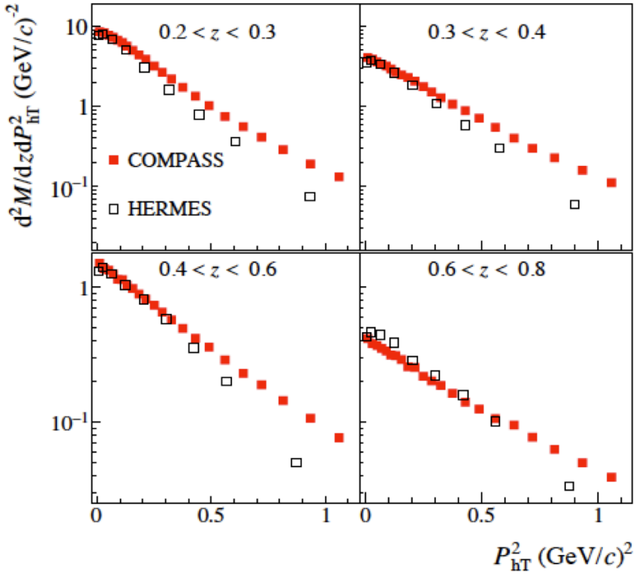


Increase of Q^2 range

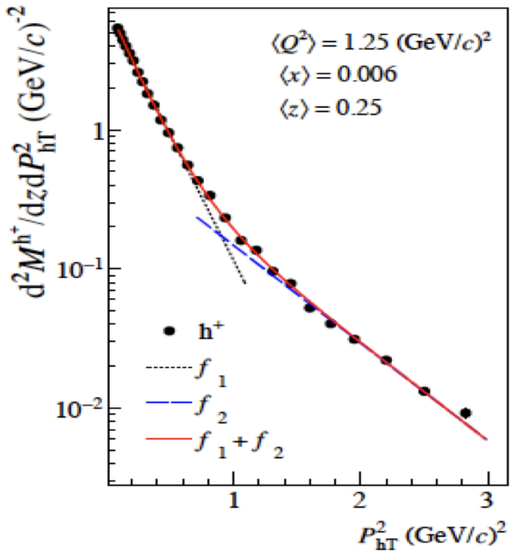


- Possible to more cleanly separate pure twist-2 CFFs with suppressed higher twist (3) contributions
- The relevant Q_{2b} range for the Q_n scaling test significantly icreases with 18/22 GeV beam





Increase of P_T range

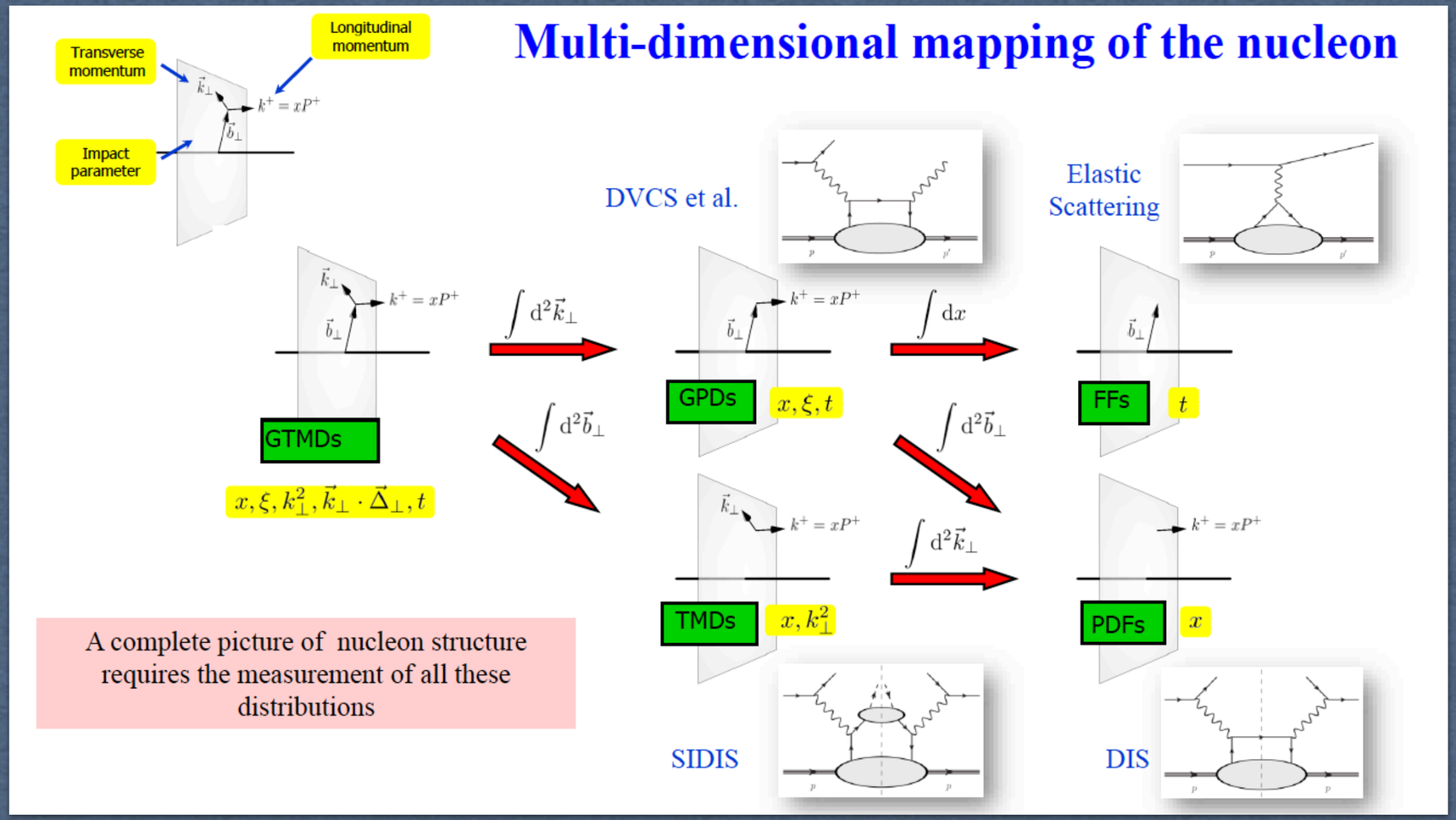


- TMDs universal, so what is the origin of the difference observed?
- What is the origin of the "high" PT (0.8-1.8) tail? Perturbative/non perturbative contributions? significantly increases with 18/22 GeV beam
- JLab: not enough energy to produce large PT
- HERMES: not enough luminosity to access large P_T

Larger PT range and high luminosity is the key for a better insight i

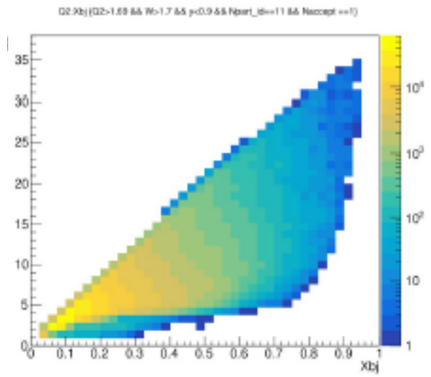
Physics opportunities: GPD and exclusive reactions

- Exp and theor. motivations
- Nucleon tomography: GPD, TMD, PDF, FF, …
- Nucleon angular momentum
- Forces distribution in the proton: Gravitational FF
- DVCS as leading exclusive channel to extract GPDs
- proton and neutron data
- Observables: Xsec (Hall-A/C), Asym (Hall-B)
- Lattice progress
- Role of higher twists
- Future:
  - polarized positron beam: charge asymmetry
  - hi-lumi: DDVCS
  - higher energy: extended kinematics

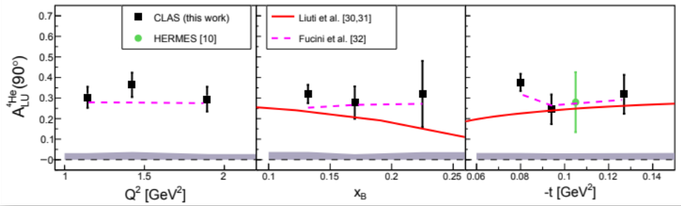


Physics opportunities: nuclear structure

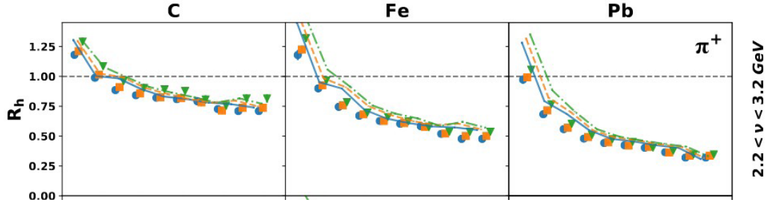
Nuclear PDFs
- Large coverage in valence region
- Significant contribution expected



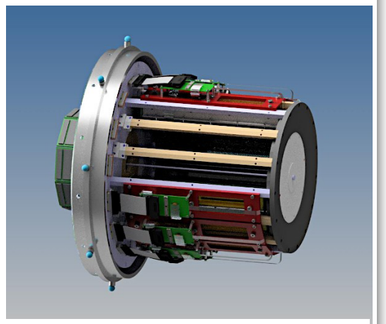
Nuclear DVCS
- Coherent He DVCS
- Large SBA observed

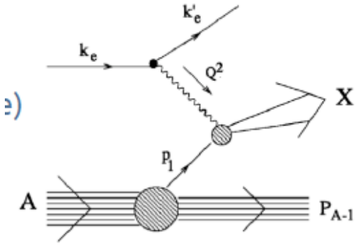


Hadronization
- Fragmentation dynamics
- Transport coefficient



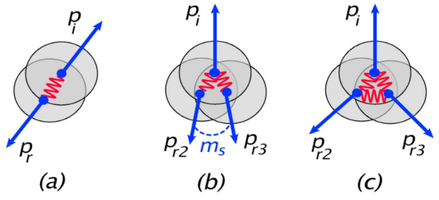
ALERT
- A Low Energy Recoil Tracker
- Tagging nuclear reactions



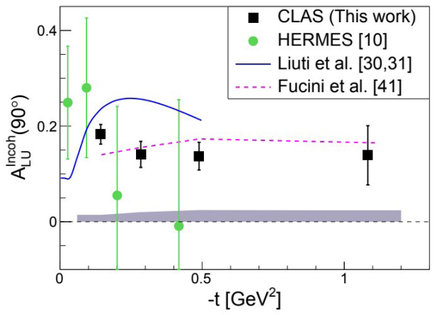


Nuclear Structure @ JLab
- Nuclear structure still remains to be understood (EMC)
- Use both structure functions (PDF, GPD, TMD, …) and other measurements (SRC, hadronization, x>1, …)

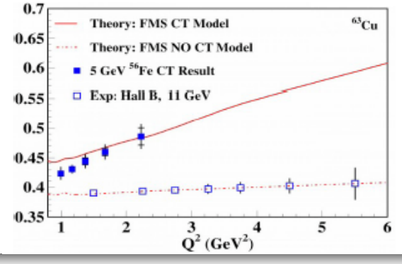
Short Range Correlations
- pn dominance observation
- 3N SRC will be studied at hi-lumi/hi-E



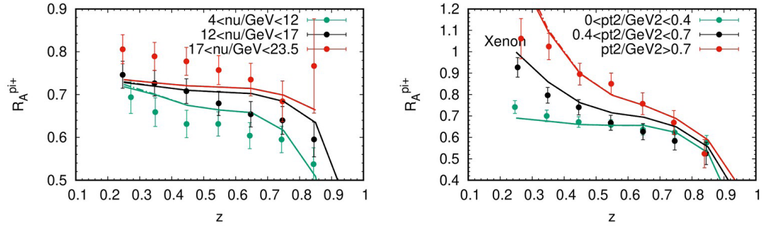
Incoherent He DVCS
- Unexplained behaviour
- A new kind of EMC effect?



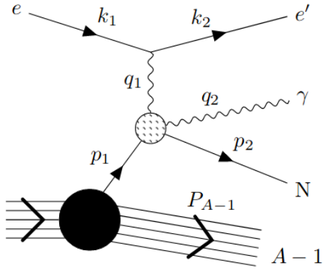
Color Transparency



Nuclear TMDs



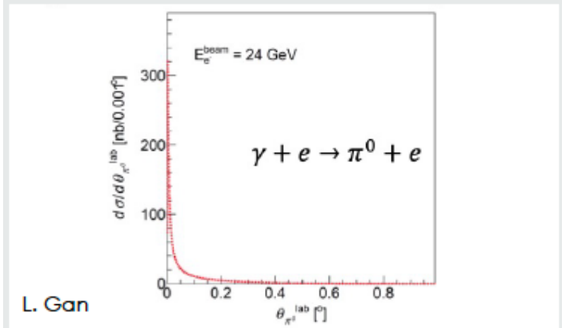
Incoherent DVCS



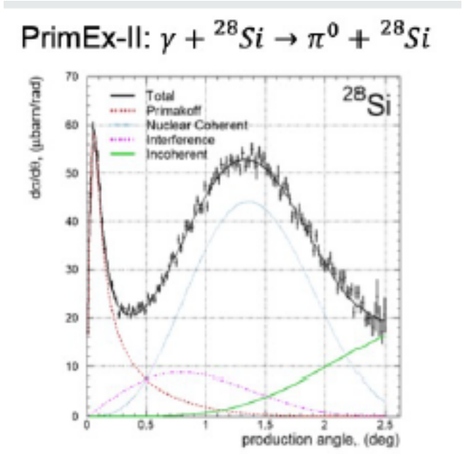
Physics opportunities: BSM

Expanding the Primakoff program @ 24 GeV

- Precision measurement of decay width $\Gamma(\pi^0 \to \gamma\gamma)$ and transition form factor $F(\pi^0 \to \gamma * \gamma)$ via the Primakoff effect off an electron target
- Measure neutral axial coupling of proton via Primakoff effect
- Search for new sub-GeV gauge bosons (scalars and pseudoscalars) via the Primakoff production



Measurement	Reaction	E_{th} (GeV)
$\Gamma(\pi^0 \to \gamma\gamma)$	$\gamma + e \to \pi^0 + e$	18.0
$F(\pi^0 \to \gamma^*\gamma)$	$e + e \to \pi^0 + e + e$	18.1



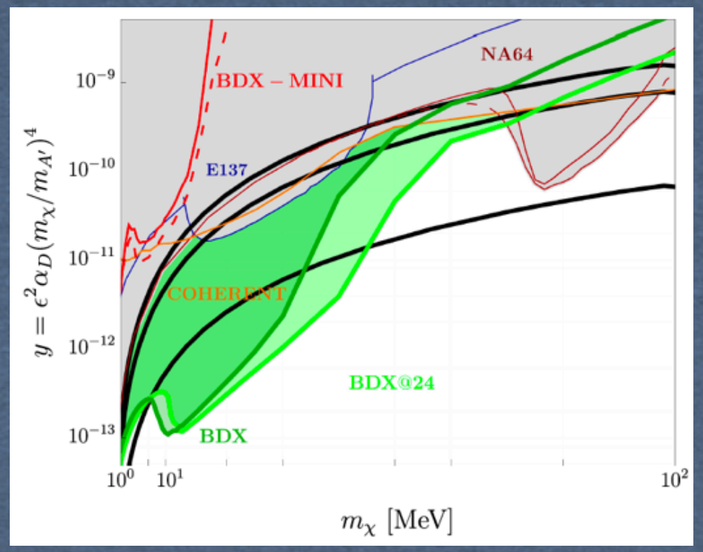
Science 368, 506-509 (2020)

Beyond hadronic physics with secondary beams at 24 GeV

- LDM (if it exists): extension of the BDX experiment
- Neutrino beam: up to 10^{18} nu/year/mq, with Decay-At-Rest Eenrgy spectrum
- Muon beam: focused beam, up to 10^{10} mu/s with energy up to 14 GeV
- Extention of e4nu program successfully runnin g at 12 GeV

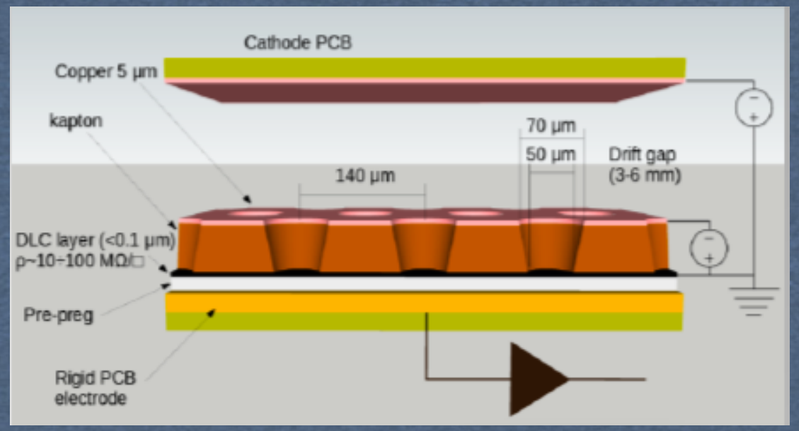
Searching for Light Dark Matter in a Beam-Dump experiment

- Extension of the current LDM searches at 24 GeV
- Unique sensitivity to LDM scenarios (inelastic LDM)
- Complementarity to the current program



CLAS12 HI-LUMI upgrade

- CLAS12 High Luminosity operation included in the Lab Agenda
- Upgraded tracker (DC to μ-RWELL)



μ-RWELL features and performance:

- Compactness
- Easy assembly and powering
- Intrinsic spark quenching
- Gas gain: 10^4
- Rate capability HR version: 10 MHz/cm2
- Rate capability LR version: 100 kHz/cm2
- Spatial resolution: down to 60 μm
- Time resolution: 5-6 ns

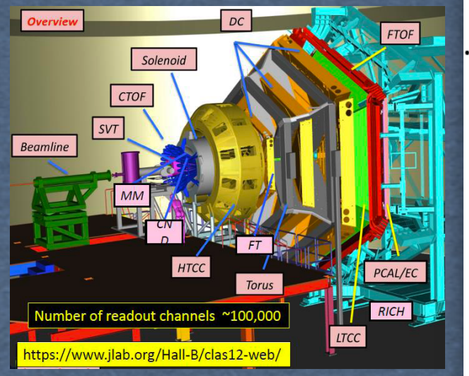
Summary: Goals for the Upgrades

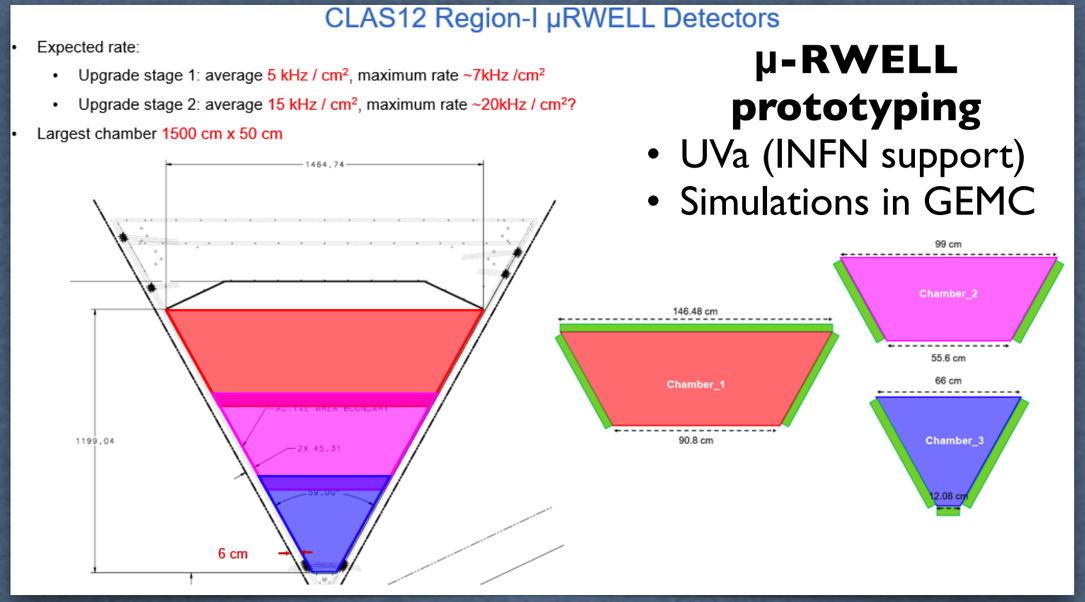
- **Stage-1:** Achieve luminosity of $2\times10^{35} cm^{-2} sec^{-1}$ for normal CLAS12 running with charged particle reconstruction efficiency of >85%

Can be achieved within 3 years with budget of $~2M.

- Stage-2: Define a configuration of CLAS12 operations for two orders of magnitude higher luminosity, $> 10^{37} cm^{-2} sec^{-1}$

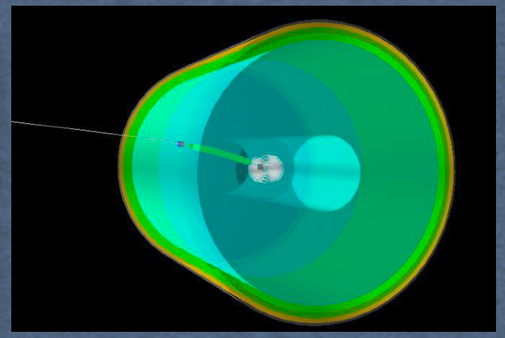
More MC studies, detector R&D and engineering are needed. TF conclusion, can be done in 7-10 years time frame with under $10M budget.

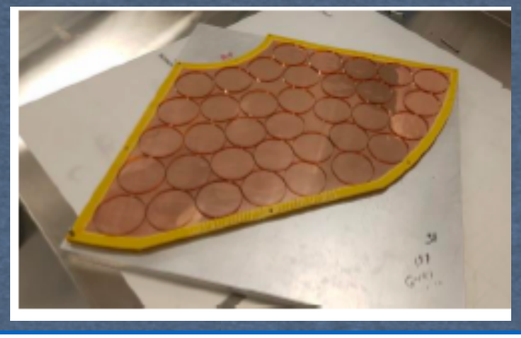




μ-RWELL prototyping

- UVa (INFN support)
- Simulations in GEMC





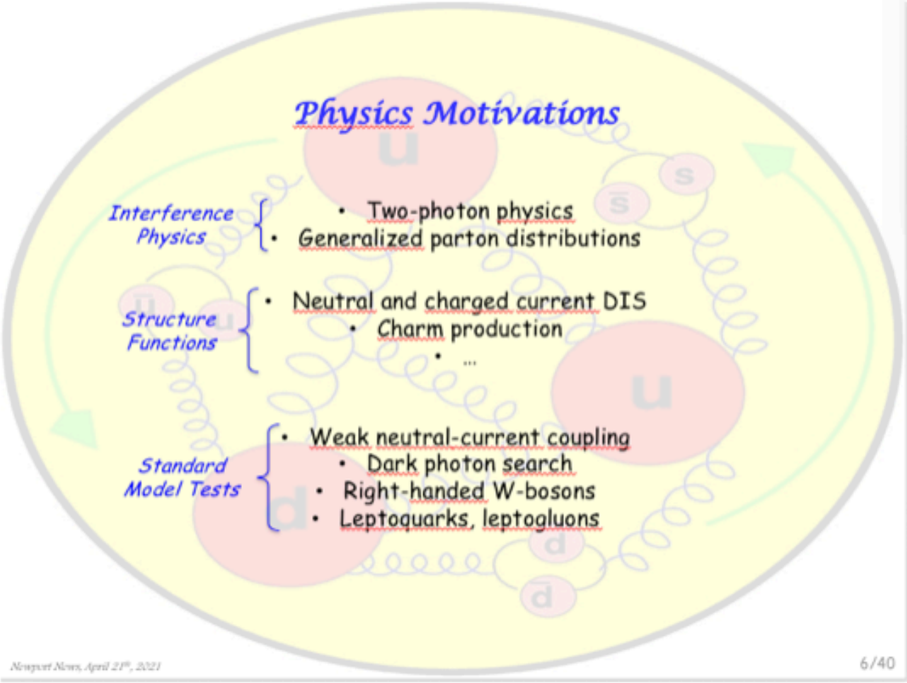
Rate requirements:

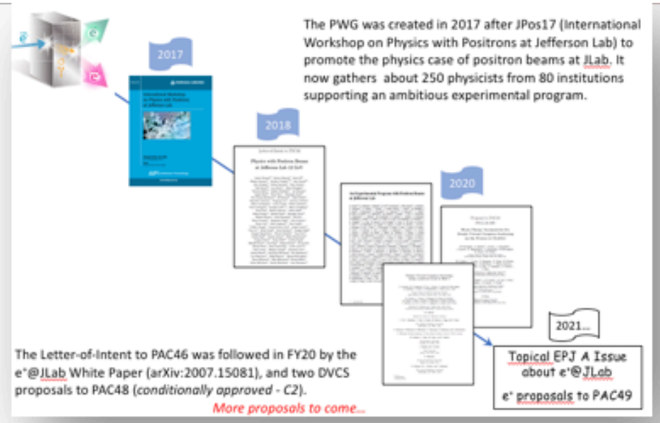
- Upgrade stage 1: average 5 kHz / cm², maximum rate ~7kHz /cm²
- Upgrade stage 2: average 15 kHz / cm², maximum rate ~20kHz / cm²
- Largest chamber 1500 cm x 50 cm

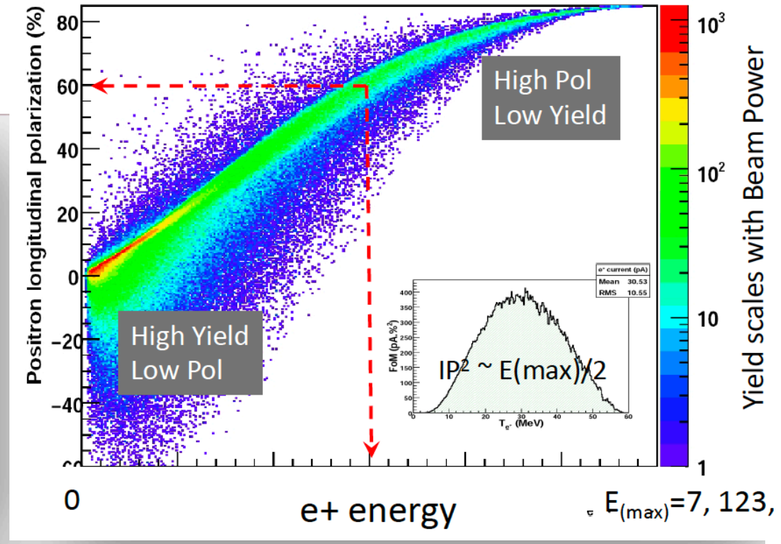
Same technology proposed for EIC: barrel tracker and low mass end cap (and PRAD-II)

JLAB positron beam

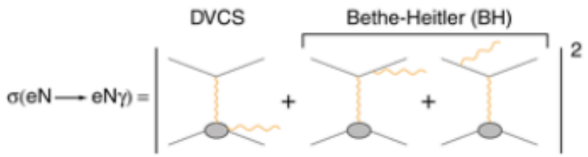
- Positron beam of high energy (up to 11 GeV), high current (I_{e+}~0.5-1uA), high polarisation (P_{e+}~60%)







Nucleon tomography and dynamics



The comparison of lepton beams of opposite charges allows to uniquely disentangle the different components of the cross section and offers an unambiguous access to the distribution of forces inside the nucleon.

The experimental determination of GPDs require a large set of observables involving unpolarized and polarized lepton beams together with unpolarized and polarized targets.

- DVCS on the proton with NPS in Hall C intends to measure cross sections with unpolarized e^+ beam. *Contact person: C. Muñoz Camacho*
- DVCS on the proton with CLAS12 intends to measure unpolarized and polarized beam charge asymmetries. *Contact person: E. Voutier*

Proposal #	Hall	Detector	p (GeV/c)	I (μA)	P (%)	Beam Nature	Beam Time (d)	PAC Result
PR12-20-012	C	NPS & HMS	6.6	5	None	e+	77	C2
			8.8					
			10.6					
PR12-20-009	B	CLAS12	2.2	0.045	60	e-	48	C2
			10.6			e+	52	

More proposals to come to PAC49.

From JLab PAC48 Report:

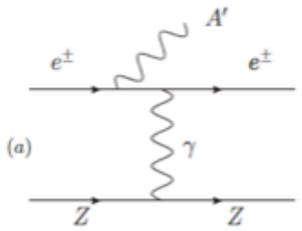
"The Committee sees great physics potential in a positron program. We encourage a vigorous effort to explore the technical feasibility of providing positron beams, and we are looking forward to receiving further proposals in this area. Clearly, it is difficult at the present stage to predict the characteristics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

Light Dark Matter search with positron beams

Submitted to EPJA as part of a topical issue on e+@JLab

A' Production mechanisms - e±

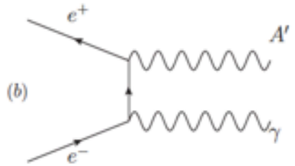
A'-strahlung



~ $\varepsilon^2 \alpha^3$

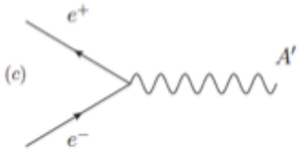
A' Production - positrons

NON-RESONANT annihilation



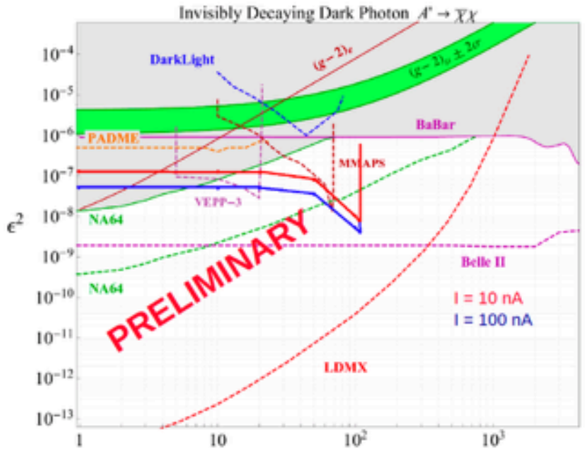
~ $\varepsilon^2 \alpha^2$

RESONANT annihilation

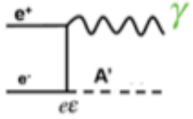


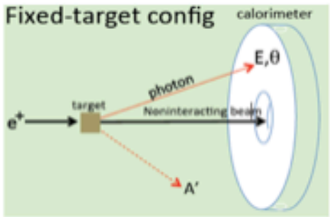
~ $\varepsilon^2 \alpha$

Thin target reach



e+ annihilation on thin target - PADME@JLAB





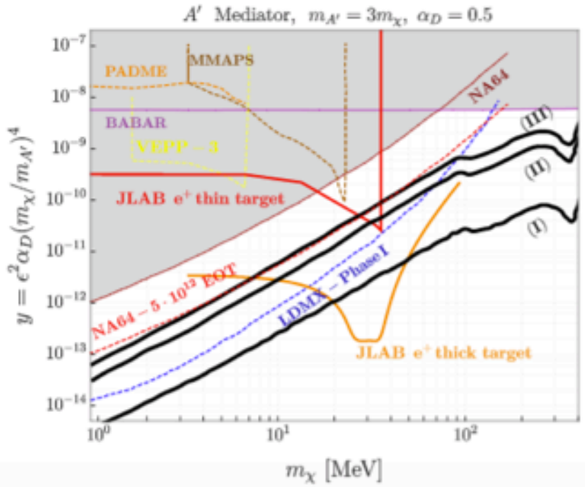
Missing mass search:
- Independent of A' decay mechanism
- Bump hunt (monophoton@collider)

- Need a positron beam
- Limited $M_{A'}$ accessible
  - 1 GeV beam: $M_{A'}$ < 31 MeV
  - 5 GeV beam: $M_{A'}$ < 71 MeV

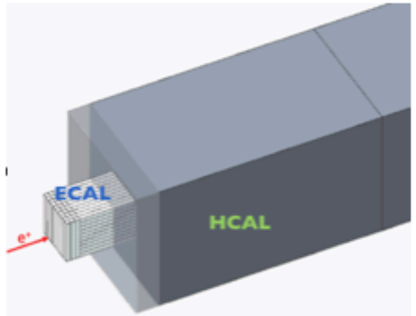
Reusable PADME components:
- Target - PADME carbon target Calorimeter -
- Ecal meets all requirements of the experiment (energy resolution, angular resolution, size)
- Veto System - technology and front-end electronics from PADME veto can be reused

New equipment:
- DAQ system - suitable for a CW beam

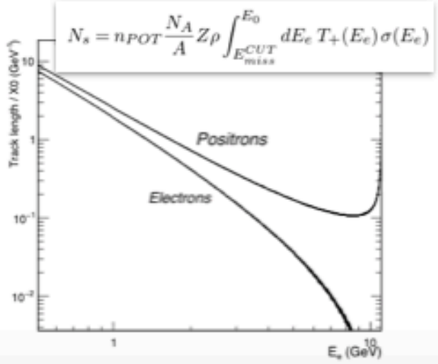
Thick target reach



e+ annihilation on thick target



- *Active* beam-dump experiment (*á la* NA64 but with positron!)
- Clear signal (peak!) due to the annihilation: $M_{A'}$ = Sqrt(2 m_e E_{miss})
- Missing energy exp (e+ Z → e+ Z' A' with A' → invisible)
- 11 e+ beam, low current
- Active target (calorimeter)
- Exclusion plots based on 10^{13} POT
- Detector: ECAL to measure e+; HCAL to veto



Conclusions

- JLab@12 GeV Physics program is in full swing
- High Luminosity upgrade in progress (CLAS12 x2) to reduce the run time for the current ops
- Positron beam under development: new opportunity in GPDs, two-photons and BSM physics programs
- CEBAF 20+ GeV upgrade is technical feasible
- New physics opportunities at high energy:
  - **Hadron spectroscopy**: XYZ states, using a photon beam to understand production mechanisms and structure
  - **SIDIS/TMD**: significant enhancement of x and Q^2 range important for better interpretation of the current theory
  - **Exclusive reaction and Nuclear structure** will benefit from a larger kinematic range
  - **BSM physics**: unique opportunity to measure Primakoff scattering on electrons and extend LDM reach with secondary muon and neutrino beams
  - **Other topics**: anti-shadowing fenomenon, precise charmonium production near threshold, …
- JLab at higher energy will bridge the current physics program to EIC hera

The lab and the user community are building the (bright) future of Jefferson Lab