J-FUTURE workshop
physics opportunities at an upgraded JLab

M.Battaglieri (INFN)

J-FUTURE workshop in a nutshell

- **First workshop dedicated to the JLab future upgrades, organised by JLab, MessinaU and INFN (IT)**
- **Hybrid format, 91 registered, on ave. ~70 attendees (~20 in-person in Messina)**
- **Three days of 30mn oral presentations (21) and three Round Table Discussions**
- **Topics:**
  - **Nucleon/nuclei structure**: DIS, SIDIS and exclusive reactions
  - **Hadron spectrum:** (semi-) exclusive (exotic) meson and baryon production
  - Hadron physics with positrons
  - **Physics beyond hadronic interactions:** Light Dark Matter, secondary beams (muon and neutrino)
  - **Infrastructures**: detectors and accelerator upgrades for a new positron beam, hi-luminosity operations, and up to 24 GeV beam energy increment
- **Organised in collaboration with JLab Theory Group, experimental Halls and Accelerator Division**
- **JLab users driven initiative**

... just the beginning

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:

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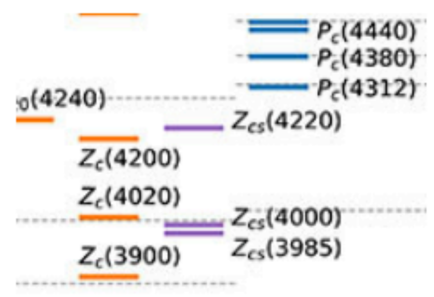

Hadron Spectroscopy with a CEBAF Energy Upgrade

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.

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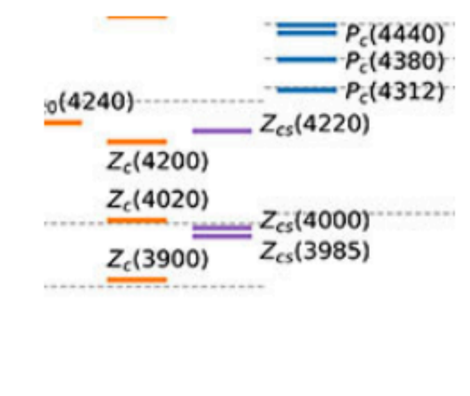

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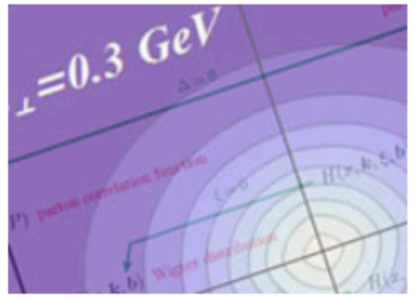

The Next Generation of 3D Imaging

July 7

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

Studies of azimuthal distributions of hadrons and photons in exclusive and semi-inclusive Deep Inelastic Scattering measurements, providing access to a variety of observables helping to elucidate the way the properties of the proton emerge dynamically from strong interactions, are recognized as key objectives of the JLab 12 GeV program, and driving force behind the construction of the future Electron Ion Collider (EIC). Jefferson Lab 12-GeV data already have remarkably higher precision at large parton fractional momenta x compared to the existing data and will be the main source of information on non-perturbative QCD in next decade. The major limitations in studies of the nucleon structure at JLab12 are the limited coverage of the kinematical region, where the non-perturbative sea is significant, and the limited phase space in accessing large momentum transfer and large transverse momenta of final state particles due to relatively low energy in the photon-nucleon CM system. These issues can be overcome by a JLab upgrade to 24 GeV.

The focus of this workshop will be threefold:

(1) Identify the flagship measurements that can be done only with 20+ GeV. **(2)** Identify the flagship measurements with 20+ GeV that can extend and improve the 11 GeV measurements, helping the physics interpretation through multidimensional bins in extended kinematics. **(3)** Identify the measurements with 20+ GeV that can set the bridge between JLab12 and EIC (complementarity)

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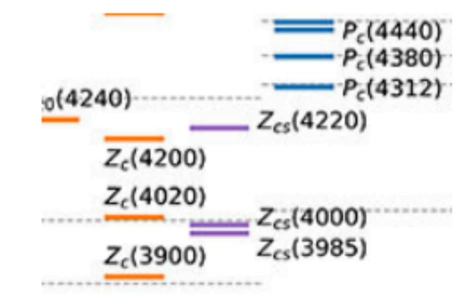

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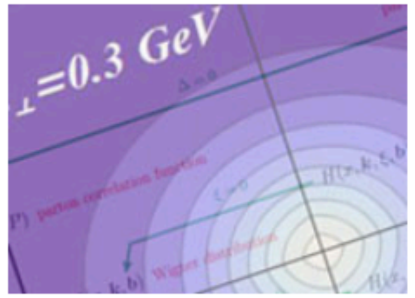

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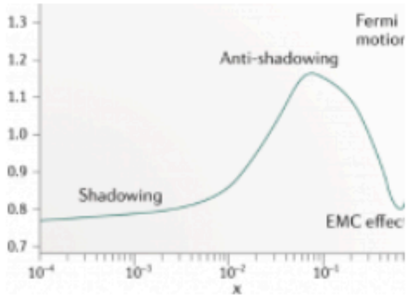

Science at Mid x: Anti-shadowing and the Role of the Sea

July 22,23

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

An upgrade of CEBAF at Jefferson Lab beyond 20 GeV will open up key science that is not possible to access at 12 GeV. One kinematic regime where this is most possible is in the "middle" Bjorken x regime around x~0.1, where the available momentum transfers at 12 GeV have heretofore limited or prevented several exciting measurements. Here, for example, the long-standing mystery of anti-shadowing may now be probed for the first time in decades. The strange sea may now be measured with minimal theoretical bias using parity-violating electron scattering. More generally, the interplay of the valence and sea regimes may be better disentangled. Novel tagged measurements may provide access to meson structure and the role of mesons in nuclei. All of these measurements leverage the unique capabilities of luminosity and precision possible at Jefferson Lab in the EIC era. This workshop seeks to enhance our knowledge of these topics and broadly identify exciting new science opened up in this middle x regime via experiments that initially utilize largely existing or already-planned Hall equipment.

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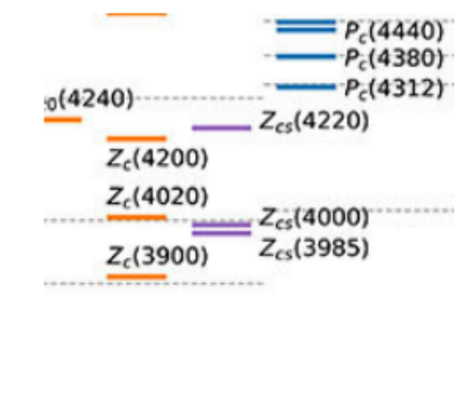

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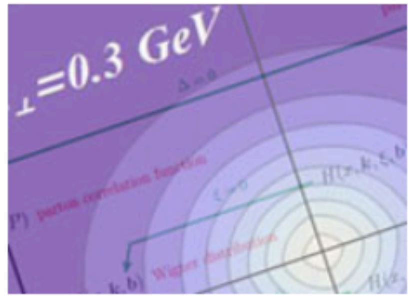

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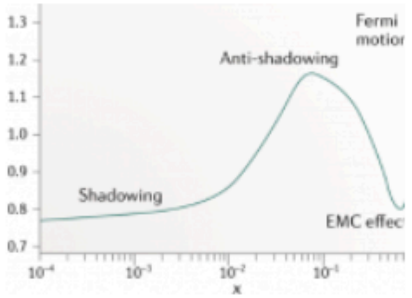

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Physics Beyond the Standard Model

August 1

Marco Battaglieri, Bob McKeown, Xiaochao Zheng

Possibilities for testing the Standard Model and searching for new physics beyond the Standard Model enabled by 20-24 GeV electron beams at C
discussed. There will be opportunities for presentations and discussions where new ideas can be brought forward.

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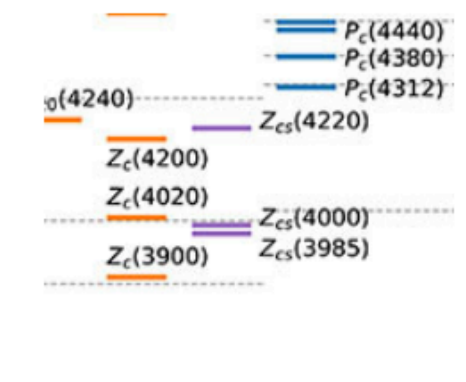

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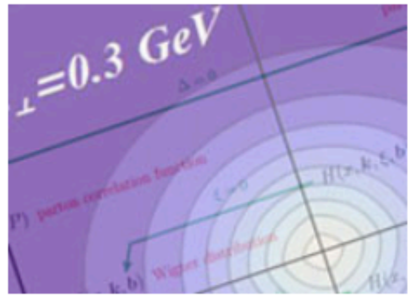

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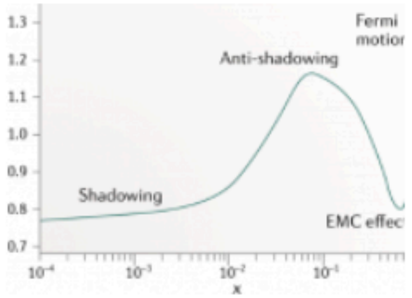

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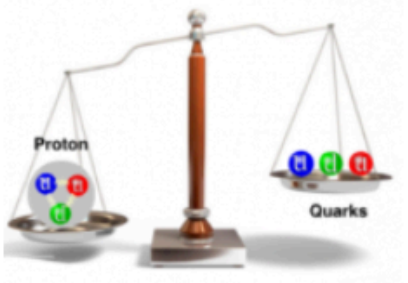

J/Psi and Beyond

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

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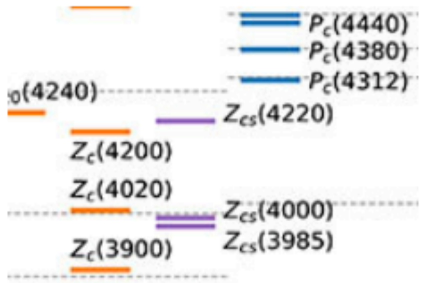

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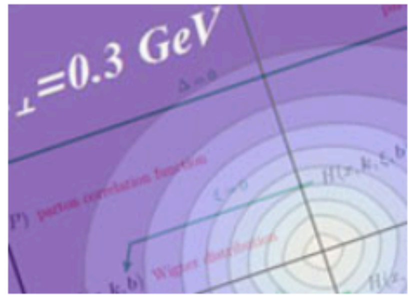

APCTP Focus Program in Nuclear Physics 2022: Hadron Physics Opportunities with JLab Energy and Luminosity Upgrade

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

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- Overview
- Call for Abstracts
- Timetable
- Contribution List
- Registration
- Participant List
- Invited Speakers
- Transportation
- Regarding COVID-19 & Visa (updated at May)
- Link to APCTP Workshop: Physics of excited hadrons

Contact
yongseok.oh@apctp.org

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 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 beam capabilities.

anwei Qiu

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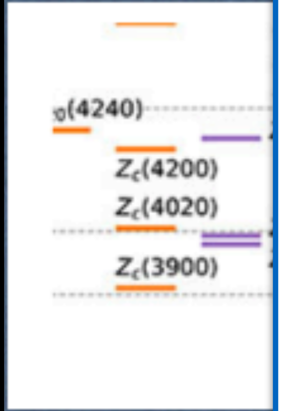
OPPORTUNITIES WITH JLAB ENERGY AND LUMINOSITY UPGRADE



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-long beams will also benefit enormously from the energy upgrade, providing access to much wider kinematic domains.

FONDAZIONE BRUNO KESSLER

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

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Physics with CEBAF at 12 GeV and Future Opportunities

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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

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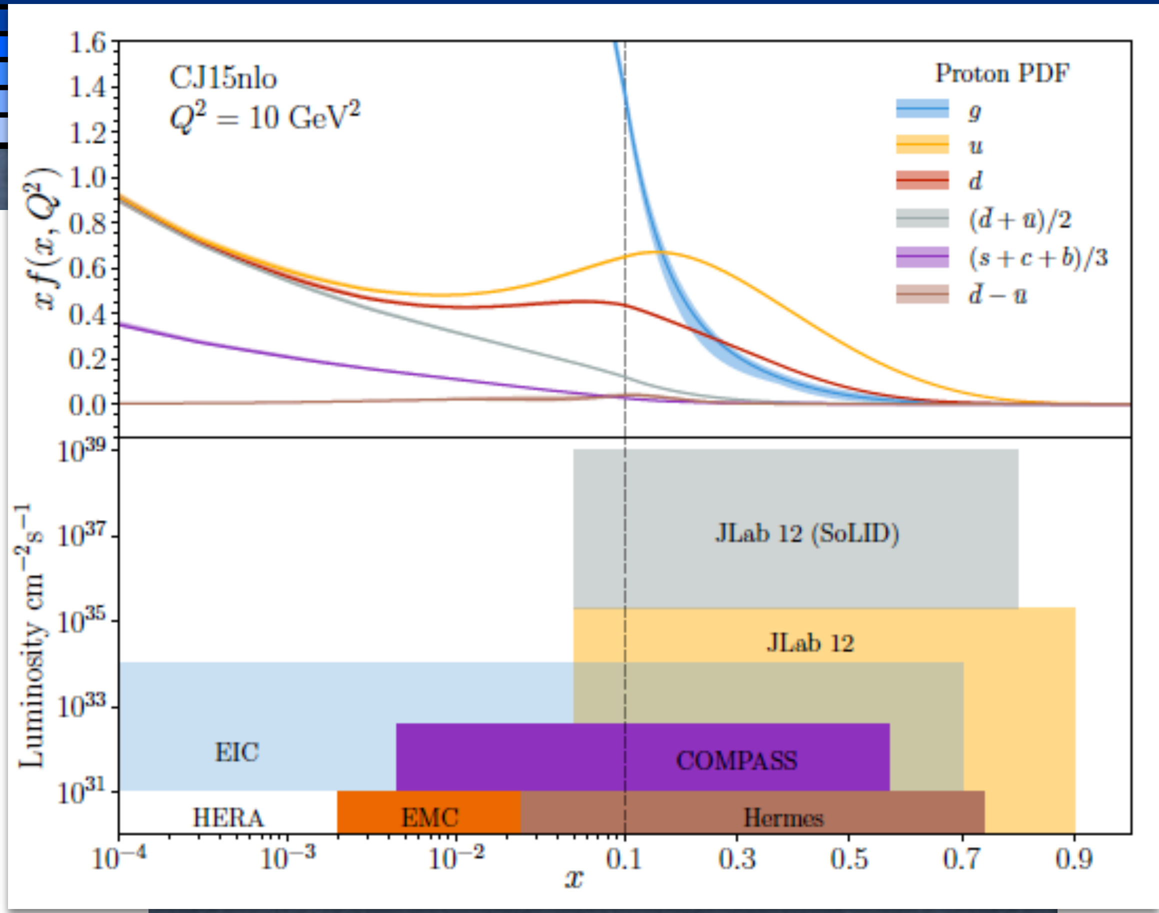
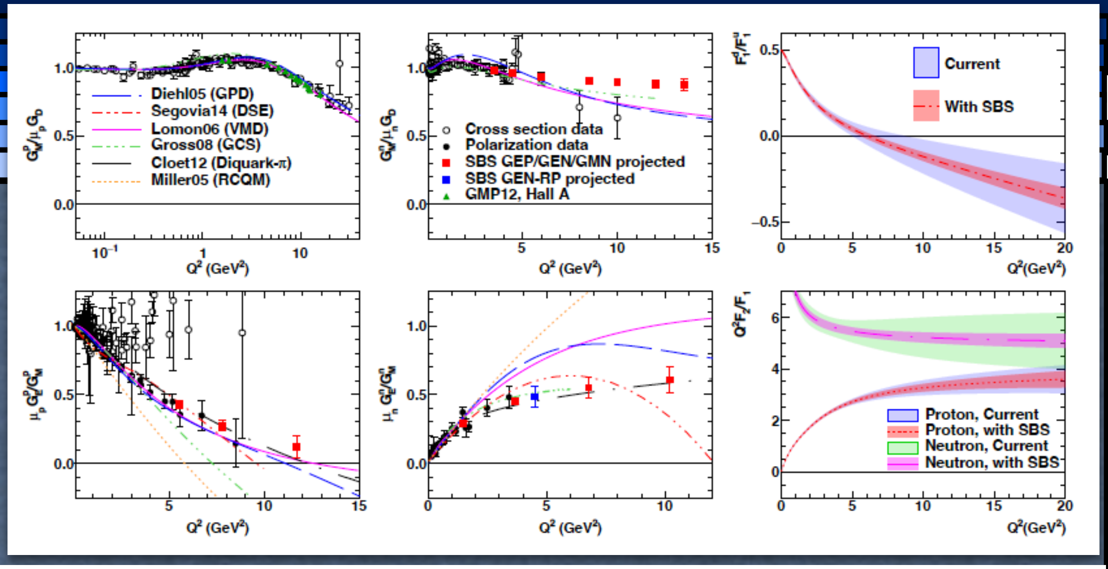
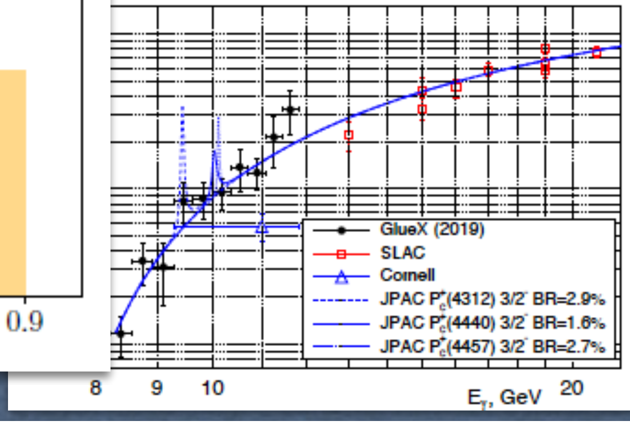
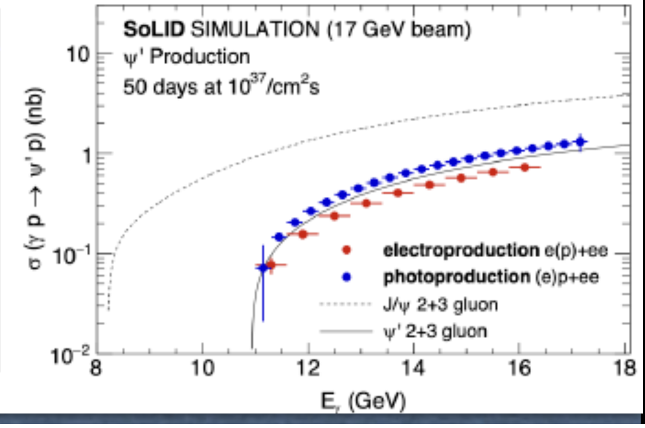
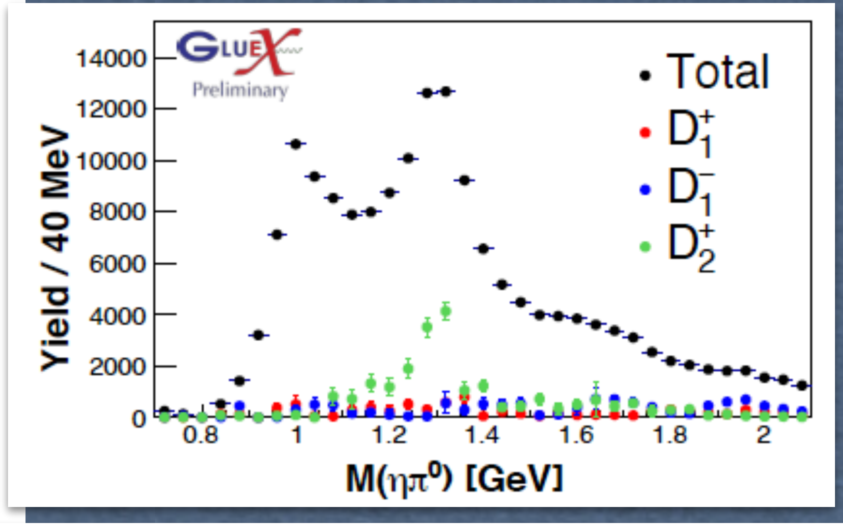
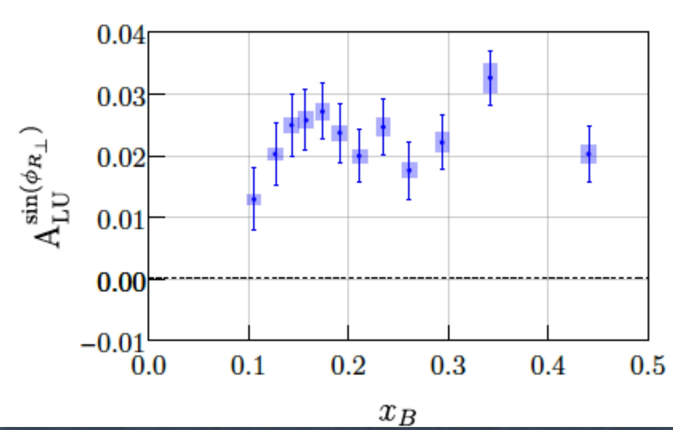


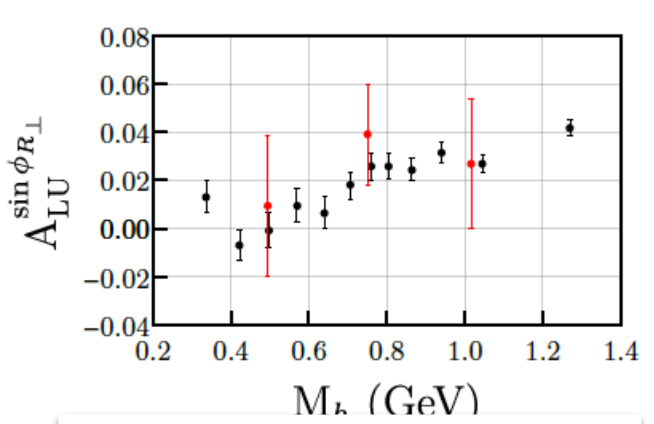


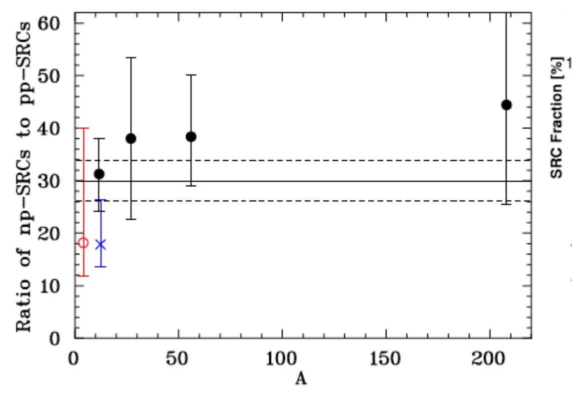


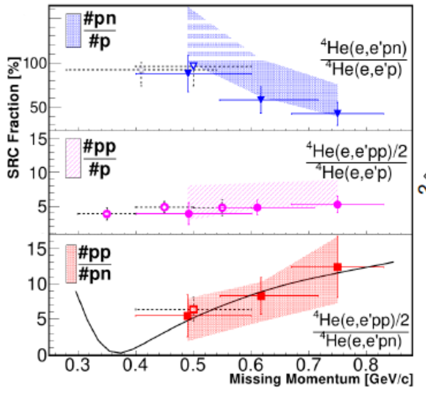


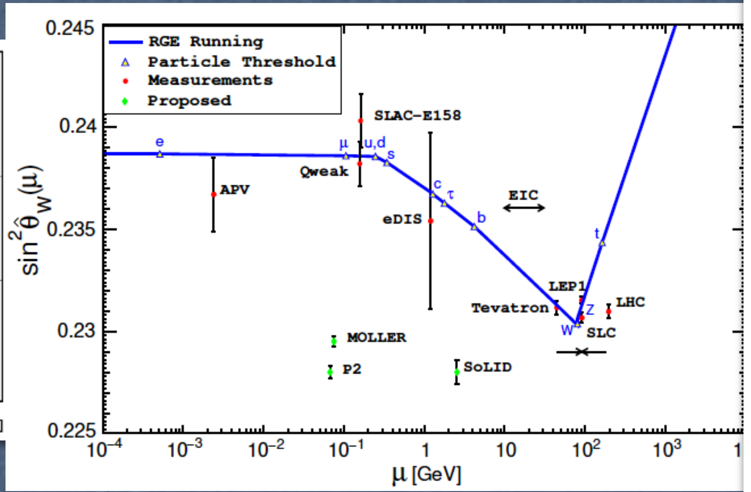


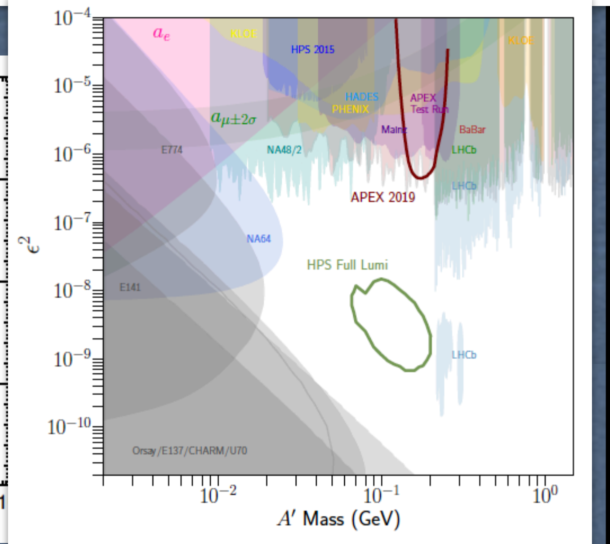












J-FUTURE

28-30 March 2022
Jefferson Lab / Messina University

Physics | **Infrastructures** | **Panel discussion**

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

The Jefferson Lab of the Future	Patrizia Rossi	Jefferson Lab / Messina University	14:00 - 14:30
Nucleon-structure studies with exclusive reactions at a future upgraded JLab	Silvia Niccolai	Jefferson Lab / Messina University	14:30 - 15:00
Theory of deeply virtual exclusive processes	Simonetta Liuti	Jefferson Lab / Messina University	15:00 - 15:30
Coffee break		Jefferson Lab / Messina University	15:30 - 16:00
Opportunities for semi-inclusive studies at high-energy (theory)	Andrea Signori	Jefferson Lab / Messina University	16:00 - 16:30
Opportunities for semi-inclusive studies at high-energy (experiment)	Harut Avagyan	Jefferson Lab / Messina University	16:30 - 17:00
Instrumentation for high luminosity upgrade of CLAS12	Annalisa D'Angelo	Jefferson Lab / Messina University	17:00 - 17:30
From CLAS to CLAS12 and CLAS24	Volker Burkert	Jefferson Lab / Messina University	17:30 - 18:00
Break		Jefferson Lab / Messina University	18:00 - 18:30
Nucleon and Nuclear structure	Alessandro Bacchetta et al.	Jefferson Lab / Messina University	18:30 - 19:30

Spectroscopy (theory)	Vincent Mathieu	Jefferson Lab / Messina University	14:00 - 14:30
Spectroscopy (experiment)	Derek Glazier	Jefferson Lab / Messina University	14:30 - 15:00
Opportunities beyond hadron physics: the physics case	Luca Marsicano	Jefferson Lab / Messina University	15:00 - 15:30
Prospects of testing electroweak physics using a positron beam at Jefferson Lab	Xiaochao Zheng	Jefferson Lab / Messina University	15:30 - 16:00
u-Channel Physics Observables at Future CLAS	Wenliang Li		
Break		Jefferson Lab / Messina University	16:15 - 16:45
24 GeV CEBAF FFA energy upgrade	Alex Bogacz	Jefferson Lab / Messina University	16:45 - 17:15
Ce+BAF : Considerations and Prospects for Polarized (and unpolarized) Positron Beams	Joe Grames	Jefferson Lab / Messina University	17:15 - 17:45
Luminosity: CEBAF Beam Power Limits	Jay Benesch	Jefferson Lab / Messina University	17:45 - 18:15
Break		Jefferson Lab / Messina University	18:15 - 18:45
Spectroscopy, Non-Hadronic, Infrastructure	Adam Szczepaniak et al.	Jefferson Lab / Messina University	18:45 - 19:45

Positrons at Jefferson Lab and the Goal of Understanding Two Photon Exchange	Axel Schmidt	Jefferson Lab / Messina University	14:00 - 14:30
Probing the partonic structure of nuclei and bound nucleons	Or Hen	Jefferson Lab / Messina University	14:30 - 15:00
Spin at high-x	Sebastian Kuhn	Jefferson Lab / Messina University	15:00 - 15:30
The MARATHON experiment with a 24 GeV JLab beam	Gerassimos Petratos	Jefferson Lab / Messina University	15:30 - 16:00
Coffee break		Jefferson Lab / Messina University	16:00 - 16:30
The psi' with SOLID	Sylvester Joosten	Jefferson Lab / Messina University	16:30 - 17:00
Opportunities beyond hadron physics: muon and neutrino beams	Antonino Fulci et al.	Jefferson Lab / Messina University	17:00 - 17:30
Opportunities beyond hadron physics: BDX, nuBDX, JPOS	Mariangela Bondi	Jefferson Lab / Messina University	17:30 - 18:00
Break		Jefferson Lab / Messina University	18:00 - 18:30
Summary	Alessandro Pilloni et al.	Jefferson Lab / Messina University	18:30 - 19:30

General

The Jefferson Lab of the Future

Patrizia Rossi

Jefferson Lab

- Lab leadership point of view
- Four pillars: NP, EIC, Data science, Acc. science
- 12 GeV program as highest priority but also positron beam and hi-lumi ops
- JLab timeline: +2030!

- In preparation for NSAC Long Range Plan
- Key challenges:
  - accelerator (feasibility, risks, timeline, costs, …)
  - physics case key experiments
  - from 6 GeV to 12 GeV to 24 GeV: cannot be a ‘natural’ extension
  - EIC competition
- Possible strategy
  - define a compelling 20 GeV physics program
  - EIC complementarity
  - Staged upgrade

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

Possible Scenarios for future CEBAF

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

J. Grames & J. Benesch’s talks tomorrow

Optimal Utilization of Cebaf
- ❖ Incremental funds
- ❖ Already included in our CE

- Energy ~24 GeV:
  - R&D ongoing

Cebaf Upgrade
- ❖ DOE Approval
- ❖ Motivation for larger community

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.

Physics

The MARATHON Experiment With a 24 GeV JLab Beam*

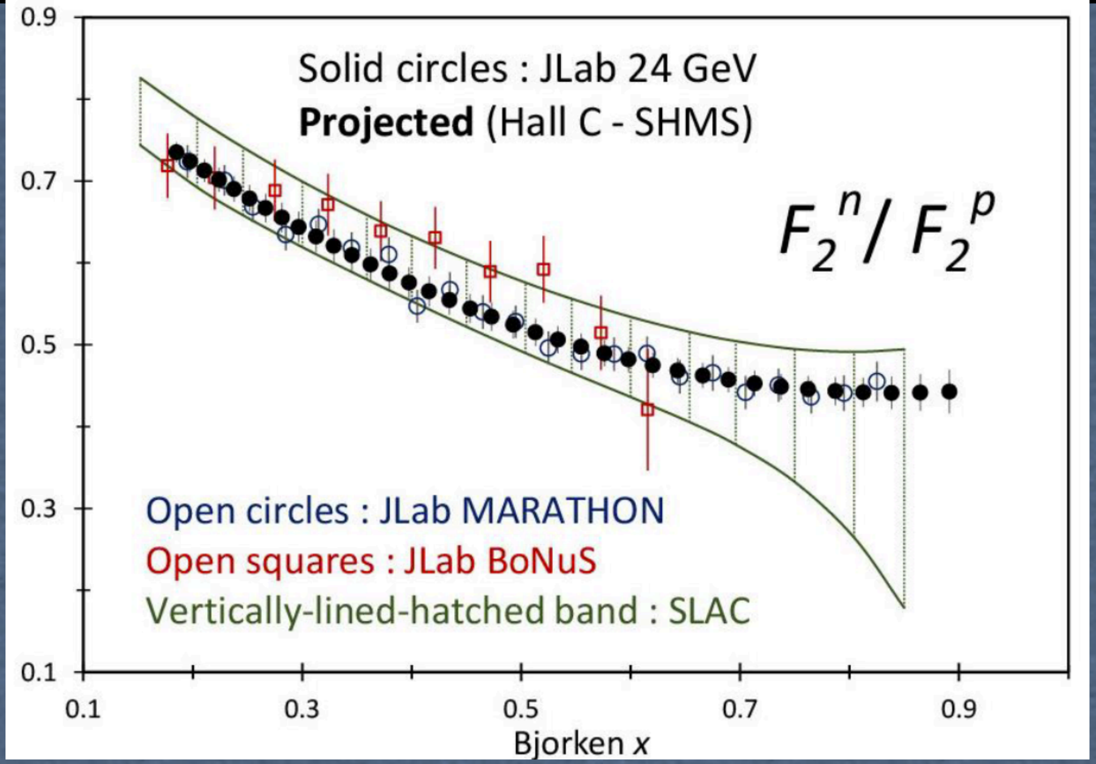
Gerassimos (Makis) Petratos

Nucleon (Spin) Structure at High X

Sebastian Kuhn

- DIS to extract proton and neutron F_2
- F_{2n}/F_{2p} in disagreement with SU(6) prediction
- MARATHON uses $^3He/^3H$
- Extension to 24 GeV would increase precision and kinematics
- BONUS used a different approach: F_{2n}/F_{2p} through spectator tagging
- Polarized PDFs: see recent JAM extraction
- At 24GeV: extension to large x

MARATHON @ 24 GeV JLab (VI)



A_{1n}

Projection using Hall C's

- HMS @ 30 deg, 4.6 GeV
- SHMS @ 20 deg, 7.8 GeV
- "F1F2-21 fit" for ^{3}He → neutron "nuclear correction"
- 30 days beam time, latest polarized 3He target performance (40cm, 50%, 30uA)
- projections (12 and 24 GeV) plotted on pQCD

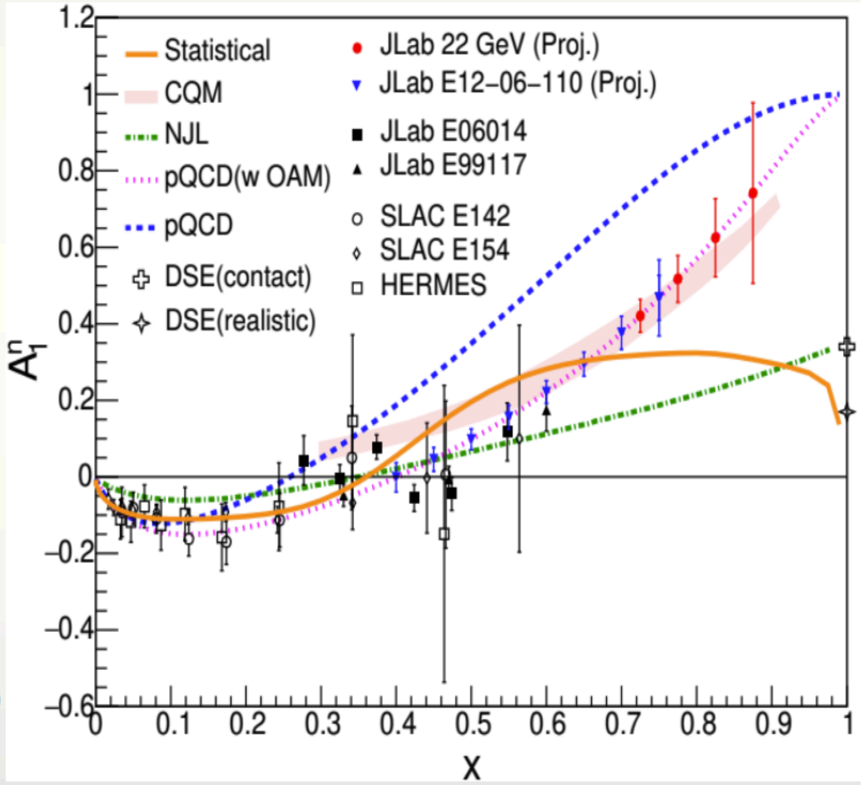


Figure credit:
Cameron Cotton (UVA/HUGS2021)
David Flay (JLab)
Thanks to X. Zheng

Summary

- MARATHON has provided high quality F_2^n/F_2^p data at medium and large values of Bjorken x that are free of inherent uncertainties present in the SLAC data extracted from d/p DIS.
- MARATHON has also provided a high quality measurement of the isoscalar EMC effect of the $A=3$ nucleus (a nucleus made up of 1.5 proton and 1.5 neutron).
- JLab with a 24 GeV electron beam can significantly extend the kinematic range of the 12 GeV MARATHON experiment.
- SHMS in JLab Hall C can be used to extend F_2^n/F_2^p up to $x = 0.9$, doubling the MARATHON four momentum range up to $Q^2 = 22\ (\mathrm{GeV}/c)^2$, with $W^2 > 3.5\ [(\mathrm{GeV}/c^2)]^2$.
- HMS and SHMS data can be used to improve the existing MARATHON measurements of the EMC effect of the $A=3$ mirror nuclei.

Conclusions

- Structure functions in the valence region remain of high interest
- Jefferson Lab at 12 GeV will make significant impact on our understanding of this region
- 24 GeV can expand the coverage in x from 0.75 to 0.9, thereby minimizing the extrapolation to x -> 1.
- Larger range in Q^2 and higher count rates -> minimize theoretical uncertainties and increase statistics even at lower x.
- 24 GeV necessary to close the gap with EIC
- Remaining issues: extracting neutron (polarized) structure functions from measurements on nuclei (d, ^{3}He).

Physics

Opportunities for semi-inclusive studies at high energies

Andrea Signori

University of Pavia, INFN, Jefferson Lab

Harut Avakian (JLab)

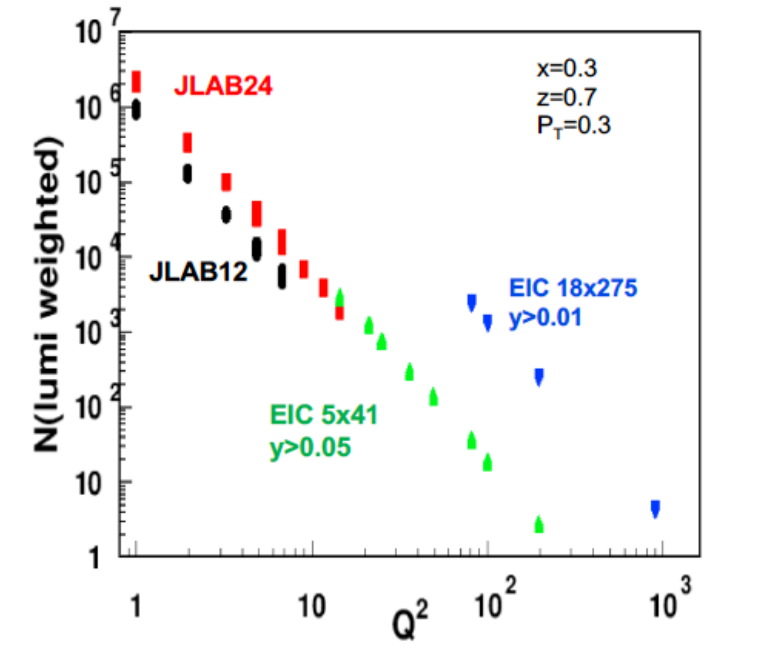
- Exp and theor. motivations
- Spin-orbit correlations in SIDIS
- Lesson learned: PT, hadron correlations, role of Q2
- TMDs evolution at high energy
- Role of polarisation observables
- Role of higher-twists
- TMD factorisation
- Complementarity with EIC
- Impact studies (how JLab@24GeV will constraint the TMD extraction)

nucleon pol. \ quark pol.	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1,\ h_{1T}^\perp$

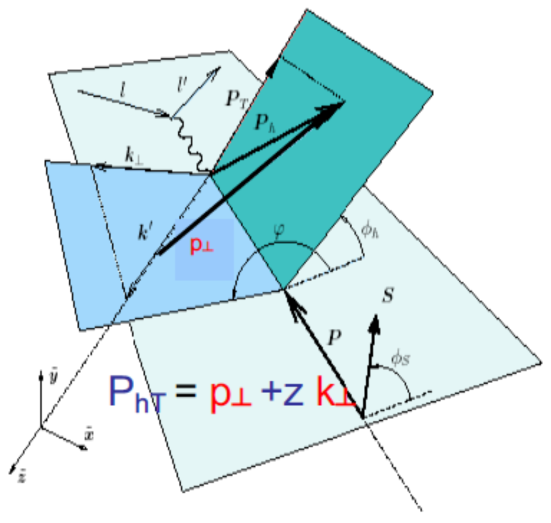
8 TMD PDFs at leading twist

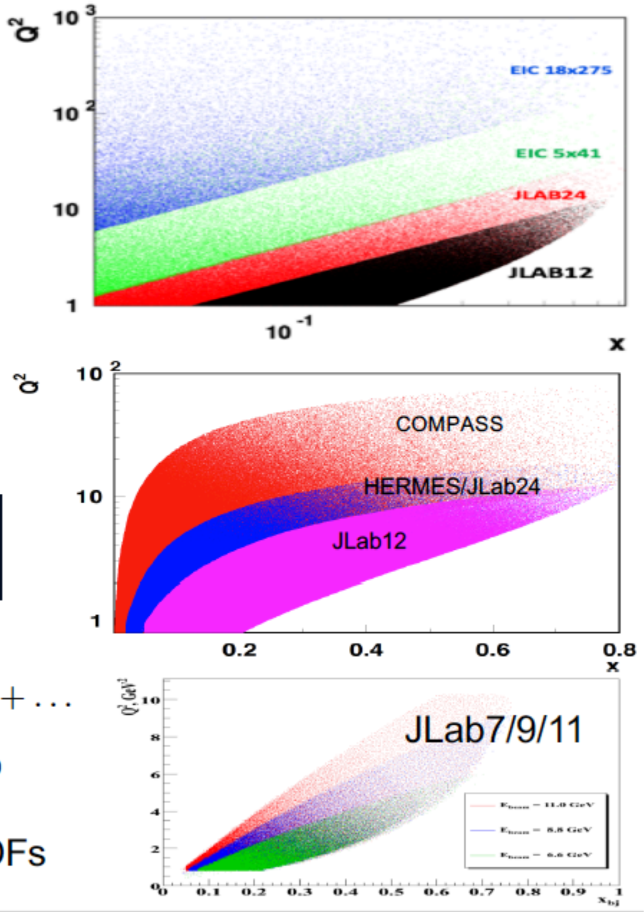
hadron pol. \ quark pol.	U	L	T
U	D_1		$H_1^\perp$
L		G_{1L}	$H_{1L}^\perp$
T	$D_{1T}^\perp$	G_{1T}	$H_1,\ H_{1T}^\perp$

8 TMD FFs at leading twist



SIDIS kinematical coverage and observables

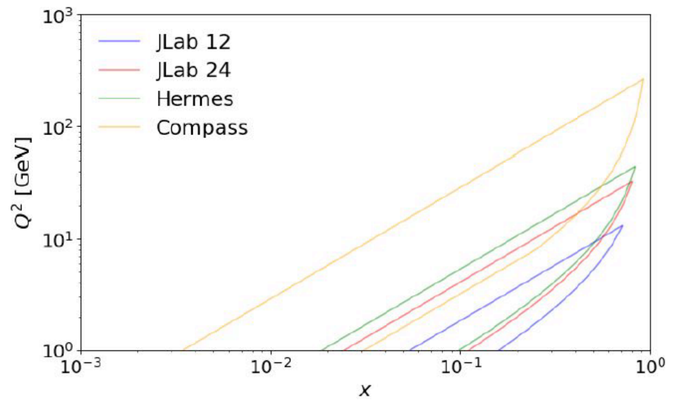




$$\sigma \propto F_{UU} + P_b\sqrt{2\epsilon(1-\epsilon)}F_{LU}^{\sin\phi}\sin\phi + P_t\epsilon F_{UL}^{\sin 2\phi}\sin 2\phi + \dots$$

- Studies of azimuthal modulations give access to underlying 3D partonic distributions
- QCD predicts only the Q^2-dependence of 3D PDFs

Conclusions and homework



The motivations for adding "**JLab 24**" should rely on the power of this data to *"**enrich**" the picture, but not to "**clean**" it* from the point of view of the formalism

Fundamental insights into:
- non-pert. large x region
- polarization
- flavor separation
- collinear distributions (?)
- ...

But same "complications" as the other fixed-target experiments

WE NEED IMPACT STUDIES!

Summary

•Multidimensional measurements of spin-azimuthal modulations in single and di-hadron production in SIDIS, are critical for interpretation of observed significant correlations between hadrons, both in CFR and TFR

•Extending JLab measurements to a wider range in Q^2 and P_T with energy upgrade, will be crucial in studies of evolution properties of underlying PDFs, and separation of higher twist contributions, critical for understanding the QCD dynamics

•Realistic projections have been performed using the existing CLAS12 software, with the existing CLAS12 acceptance, showing complementarity with CLAS12 and EIC

•Proposed measurements with upgraded JLab, will be the part of SIDIS studies in motivating the upgrade (suggested for the flagship list).

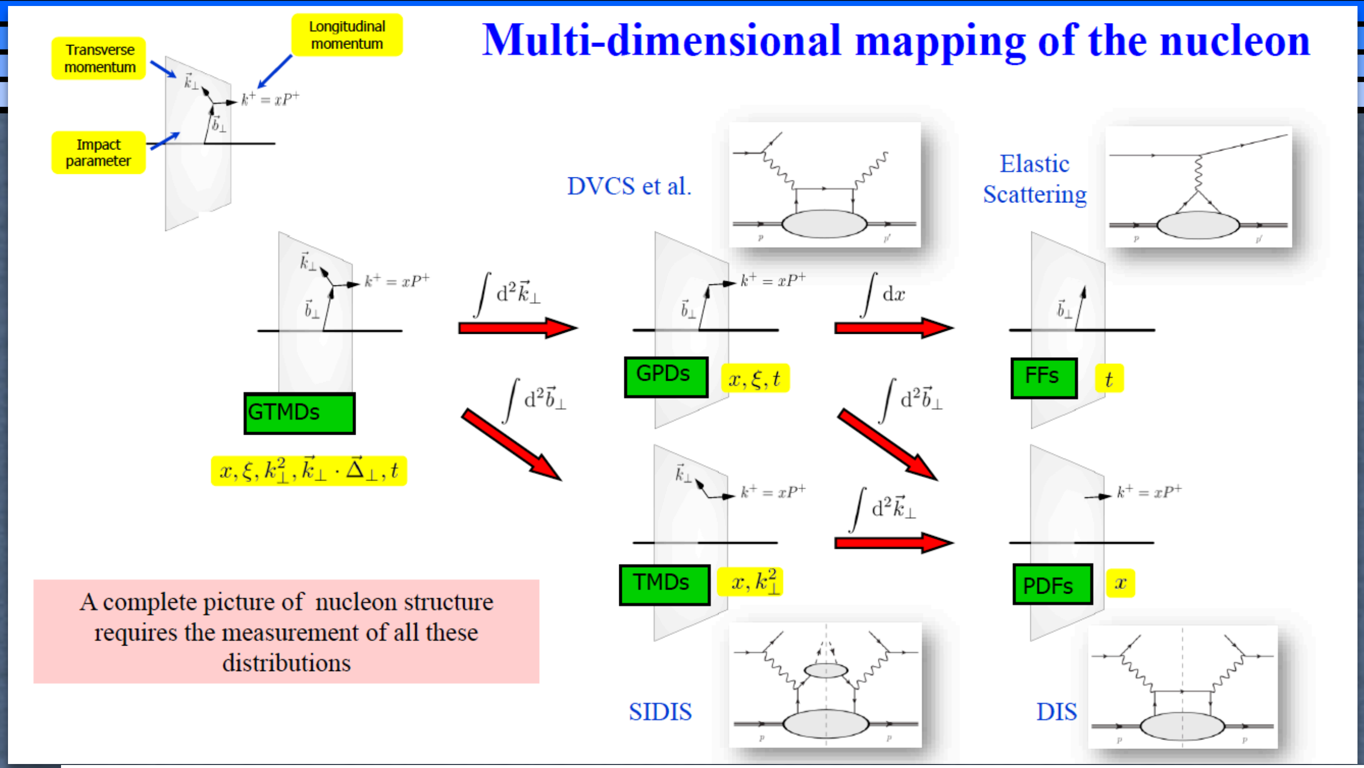
Physics

Nucleon-structure studies with exclusive reactions: perspectives for upgrades at JLab

Silvia Niccolai, IJCLab Orsay

SIMONETTA LIUTI
UNIVERSITY OF VIRGINIA

- 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



Conclusions and outlook

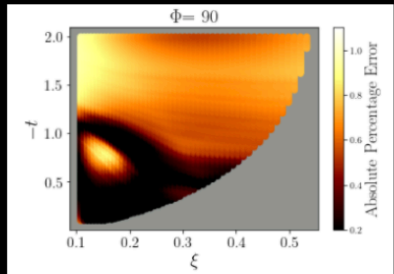
- Exclusive reaction can provide a **wealth of information on nucleon structure**, via the measurement of **GPDs**: nucleon tomography, quark angular momentum, distribution of forces in the nucleon
- **pDVCS** has been and is being **extensively measured**, aside from **beam-charge and transverse-target observables**
- **nDVCS** measurements are ongoing, **cross sections and asymmetries are very small** → **higher luminosity** would be welcome, as well as measurements of **BCA**
- **TCS & DDVCS** are the **golden channels** that should be explored in the future to go beyond DVCS: universality of GPDs, real part of CFFs, x dependence of GPDs
- **Higher beam energy** will increase the **phase space for DVCS**, but also **lower cross sections** (strong BH dominance?); PID and backgrounds need to be studied; likely beneficial for **DVMP** measurements, but **let's have a look first at 11-GeV data**
- To have an **upgraded JLab** (CLAS12) **coexisting and competing with the EIC**, we should prove that it allows **UNIQUE physics**, not only **complementary kinematics**: pointing towards the measurements of **small-cross-section and unmeasured reactions/observables requiring high luminosity and/or polarized positrons beam can be a good strategy**; higher energy alone (without positrons and/or DDVCS) doesn't seem to me to lead to a strong enough physics case, at least in the GPDs field
- **Ideally, we should aim for high-lumi, energy, and positrons** ☺
- The CLAS Collaboration held sessions dedicated to the upgrades in the last 3 meetings; open discussion at the last meeting showed **strong interest in the community**; support from JLab management for Users' initiatives towards upgrades
- Next steps? Involving theorists for predictions; realistic simulations; LOIs & PAC proposals? R&D for detector developments?

CONCLUSIONS

- We presented avenues to identify observables sensitive to both longitudinal and transverse OAM
- Jefferson Lab @24 GeV will make history as the we uncover the mechanical properties the of the proton and observe its spatial images!
- To observe, evaluate and interpret GPDs and Wigner distributions at the subatomic level requires stepping up data analyses. To accomplish this we need
  - Physics motivated cross section formulation
  - Develop methods to extract quantities from data including numerical/analytic/advanced ML and quantum computing method

This program is on its way! We would be happy to interact

UVA+ODU ML group



We lack measurements where FF discrepancy is large.

We don't have any measurements where partonic and hadronic calculations interface.

We have no facility with a positron beam and state of the art detectors.

We are at the cusp of a major campaign to look at 3D nucleon structure.

Physics

Positrons at Jefferson Lab and the Goal of Understanding Two Photon Exchange

Axel Schmidt

***u*-Channel Physics Observables at Future CLAS**

Wenliang 'Bill' Li

Two-photon exchange concepts at Jefferson Lab

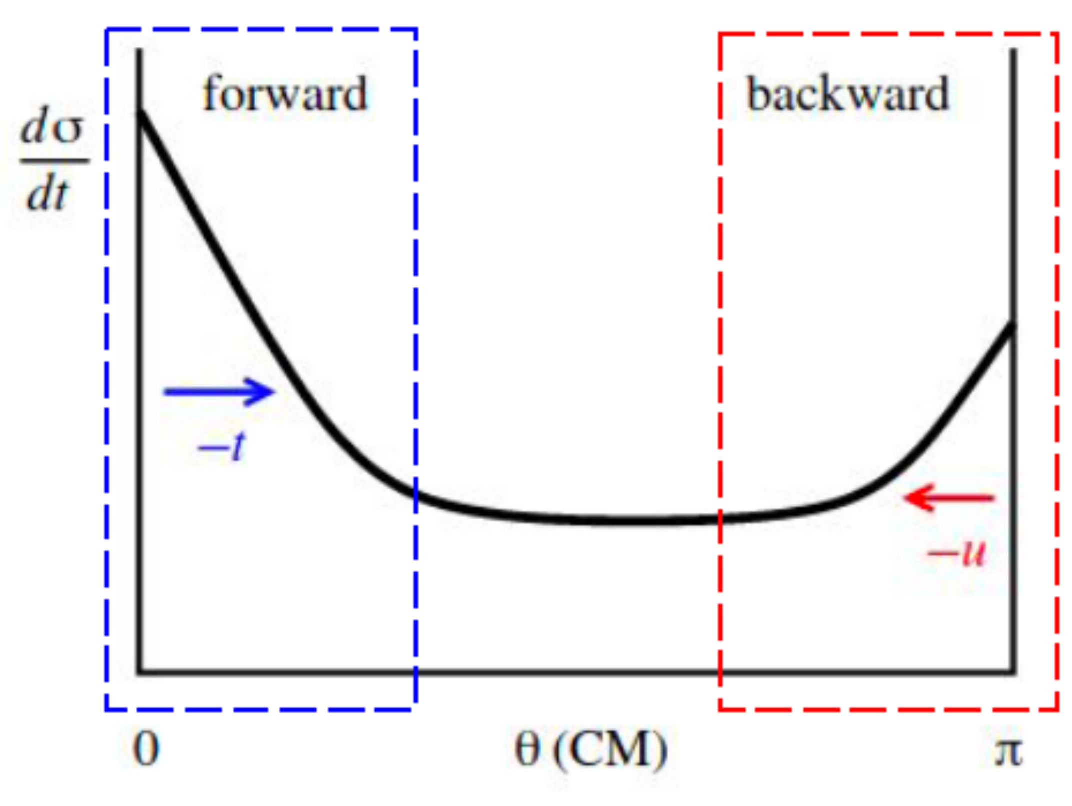
- e^+p/e^-p at CLAS12
  - J. C. Bernauer et al.
  - Campaign to map out TPE once and for all
- e^+p/e^-p at SBS
  - E. Cline et al.
  - Quick, targeted measurement at low-ϵ
- e^+p super-Rosenbluth, Hall C
  - J. Arrington, M. Yurov
  - Demonstrate opposite bias in G_E/G_M
- e^+A/e^-A in Hall C
  - T. Kutz et al.
  - First measurement of TPE on nuclei
- e^+ polarization transfer at SBS
  - A. J. R. Puckett et al.
  - Show ϵ-dependence comes from TPE
- Target-normal single spin asymmetry at SBS
  - G. N. Grauvogel et al.
  - Imaginary part of TPE amplitude

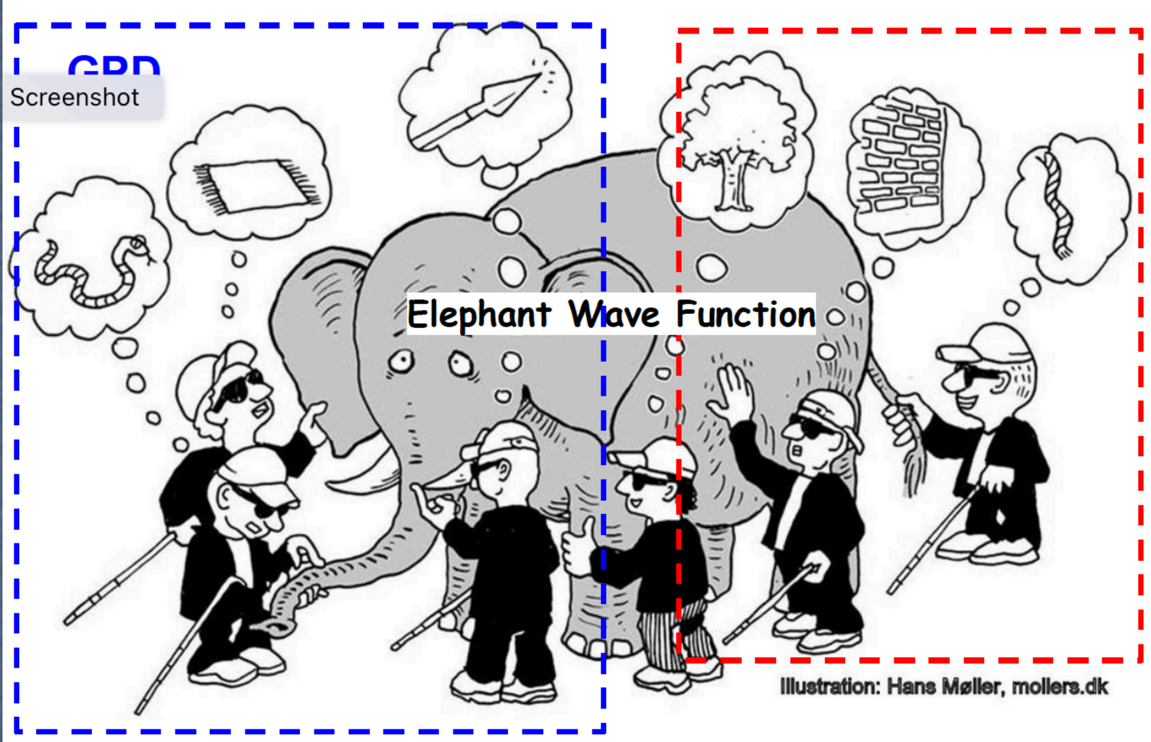
Conclusions:

- The proton form factor discrepancy is uncomfortable, both for high-Q^2 form factors and for the upcoming campaign to map 3D nucleon structure.
- The most interesting and useful TPE measurements are $3 \leq Q^2 \leq 5$ GeV^2, to build a bridge between hadronic and partonic theory models.
- A positron beam at Jefferson Lab would allow conclusive measurements as well as open up new observables.

- **TPE via e+p - e-p Asymmetry**
- **Positron beam and CLAS12 to map TPE effect in a wide kinematic**
- **SBS for Rosenbluth separation (and pol transfer)**

- **u-channel pi0, J/Psi, DVCS**
- **hard meson production**
- **TDA complementary to GPDs**
- **Exploratory measurements at CLAS, CLAS12 and Hall-A**





We must consider to give CLAS12 and CLAS24 with appropriate equipment to probe u-channel processes.

Question to us: are we going to give-up on u-Channel study because it is too hard to understand?

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Physics

Hadron Spectroscopy

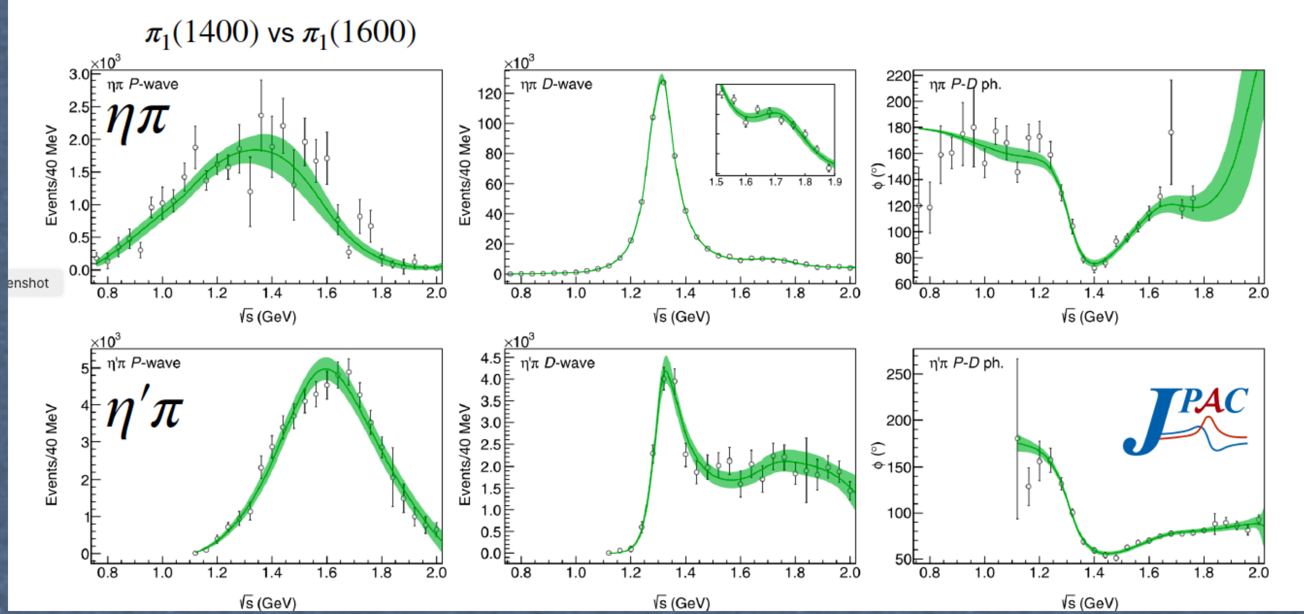
Vincent MATHIEU

Derek Glazier
University of Glasgow

- Exp and theor. motivations
- Gluonic excitations in mesons and baryons
- Theory: amplitude analysis progress
- Exp: GLUEX, CLAS, CLAS12
- J/Psi photoproiduction @12GeV and 24GeV
- JPAC support to HS at JLab
- Future: XYZ, pentaquark,
- Complementarity with EIC (γp →Z⁺X)
- Study case: toy vs. realistic simulations
- Simplified models for 24 GeV upgrade

Low Energy Fit of $L = 1,2$

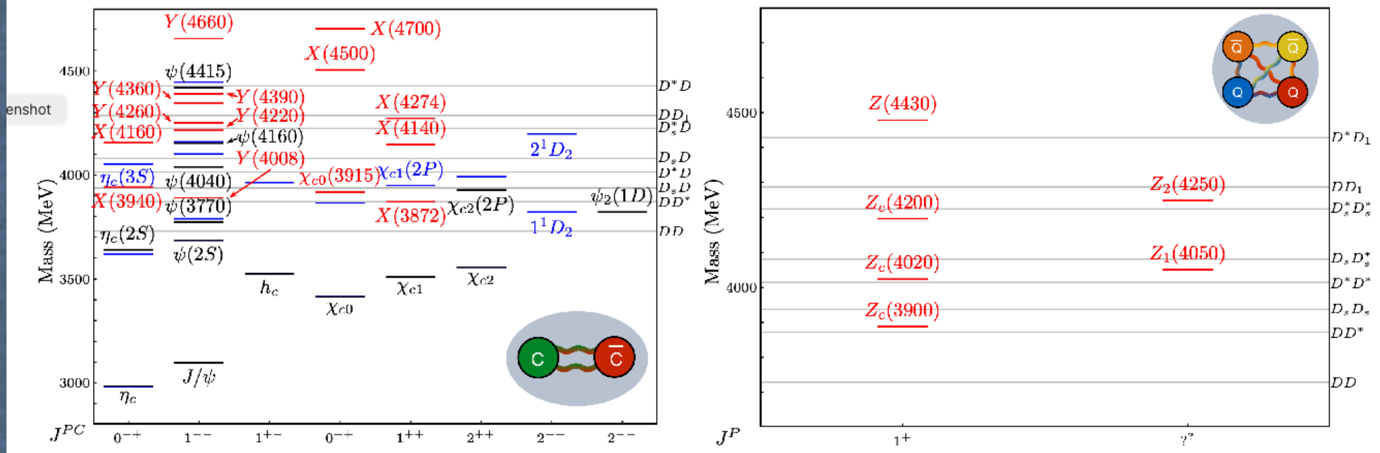
Rodas et al (JPAC) PRL122 (2019) 042002



Exp. status of XYZ

Esposito, Pilloni, Polosa Phys Rep 668 (2017) 1

Black: $c\bar{c}$ predicted and observed
Blue: $c\bar{c}$ predicted but not observed
Red: exotic candidates



Summary

Have shown initial investigation into spectroscopy with charm quarks at a possible energy upgraded Jlab

Event rates and kinematics overall look very promising

Existing detector systems may already be suitable for such measurements

Some modifications and addition of new technologies should be be investigated for increasing rate capabilities

Supplementing the acceptance of CLAS12 detector could also improve Efficiency significantly

Combination of charm spectroscopy and new technologies make this a very exciting opportunity to pursue.

Cross section and channel rate es

σ is equivalent average photoproduction cross section from threshold to 22GeV

Number per day based On $10^{35}cm^{-2}s^{-1}$ lumi.

Branching ratios
X→ J/ψππ ~5%
Y→ J/ψππ ~1%
Z_c→ J/ψπ ~10%
Z_{cs}→ J/ψK ~10%
J/ψ→ e+e- ~6%
D^0→Kπ ~4%
Λ_c → pKπ ~6.3%
Λ → pπ ~67%

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

Physics

FROM SOLID J/Ψ TO Ψ' PRODUCTION AT 24 GEV

SYLVESTER JOOSTEN

Neutral-Current Electroweak Physics with SoLID, a possible positron beam, and a possible energy upgrade of JLab

Xiaochao Zheng

SUMMARY

Screenshot

Near-threshold electro- and photoproduction of quarkonium

- **Origin of proton mass**, trace anomaly of the QCD EMT
- **Gluonic Van der Waals force**, possible quarkonium-nucleon/nucleus bound states
- Do quarkonia enable **pentaquarks** to exist?
- **Mechanism** for quarkonium production itself

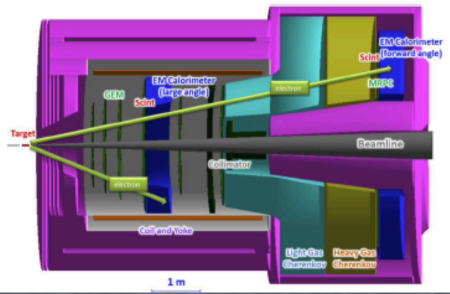
SoLID is the ultimate place to research these topics due to luminosity and kinematic reach

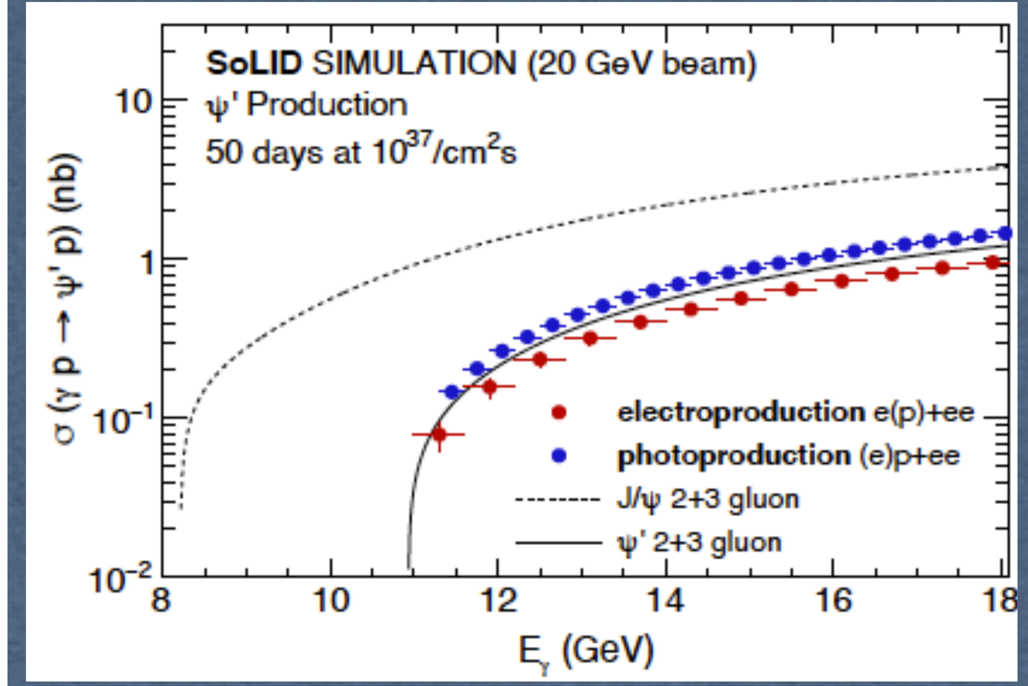
With a higher beam energy, SoLID can accomplish a complementary J/ψ and ψ' with the same detector

Higher beam energies also provide Q2 as an additional knob (comparing photoproduction with electroproduction)!

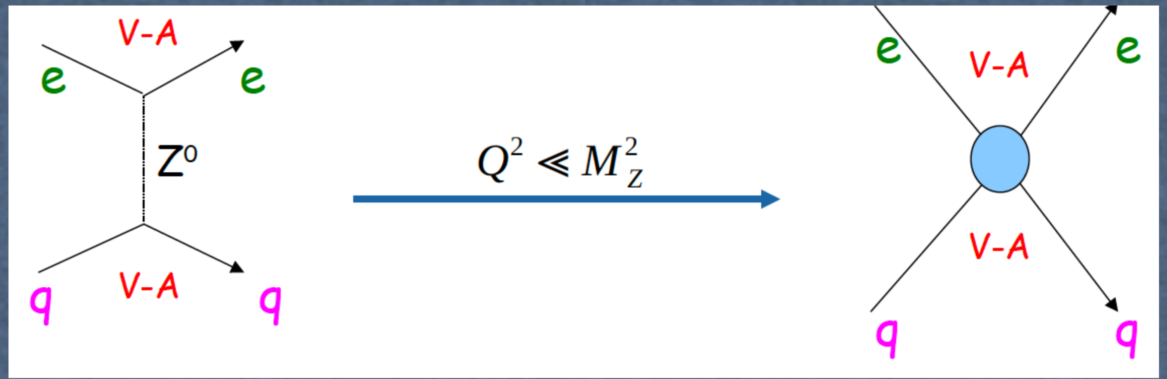
SoLID

SOLENOIDAL LARGE INTENSITY DEVICE





- Rich physics case: origin of the mass, nucleus potential
- Experimental program in Halls A,B,C: first look at threshold
- SOLID: hi-lumi precision measurement
- SOLID at 24 GeV: Psi' physics (hi-lumi + hi-energy)



Summary of Challenges and Why They Exist?

– With a positron beam, the best physics impact comes from comparison between e+ and e- scattering, rather than measuring the same observable (e.g. Apv) as electrons

– If positron vs. electron comparison is our goal, then all systematic effect related to the beam need to be controlled to high precision

Frequent ("weekly") and fast switch between e+ and e- beams is required to control differences in beam and run conditions → impact on positron beam design. We need the systematic uncertainty small enough to match statistical uncertainties (from the high luminosity)

– Measurements where signal is tiny (EW physics) will be extremely difficult

– We have not even looked into particle background effects on the detector, trigger, and DAQ system.

– There is no well established calculation nor experimental test of TPE (QED NLO) in DIS. All previous (SLAC) data indicated zero but with poor precision;

– HERA data provided only slight constraint on QED NLO in DIS – "without the QED NLO term, the fit quality isn't very good";

– We could consider a "phased" approach: study DIS TPE with 11 GeV and see if it's realistic to study EW physics with 22 GeV (?)

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- Weak neutral current coupling
- Positron and electrons (beside PV exps)
- Rich set of measurements in the past (SLAC, HERA, CERN, ..)
- Physics program at LHC, MAINZ and DESY
- SOLID and JLab@24GeV (and EIC)
- muon beams?

Physics

Opportunities beyond hadron physics: the physics case

Luca Marsicano

Future infrastructures

Mariangela Bondì

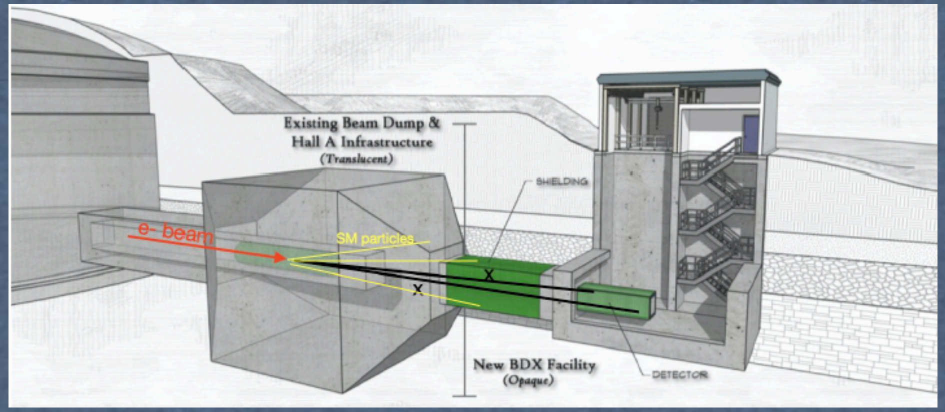
Conclusions

- Jefferson Lab features a rich BSM experimental program (HPS, BDX-mini, APEX)
- New developments are expected in the nearby future: the Beam Dump eXperiment can run in the next few years provided the new hall is built
- The realization of a positron beam at Jefferson Lab paves the way to new competitive LDM experiments
- Secondary beams produced in the Hall-A dump (muons, neutrinos) can be exploited to explore "hot" physics scenarios (proton radius, CEνNS).

- New research lines using secondary beams produced by interaction of e- beam and dump:
  - Light Dark Matter beam: BDX experiment
  - Neutrino beam: Coherent elastic ν-Nucleus scattering measurement
- LDM search with positron beams:
  - thin target approach
  - thick target approach

e+ thick
e+ thin
vBDX-CEvNS
BDX
TOMORROW
THE DAY AFTER TOMORROW
FUTURE

- Exp and theor. motivations
- Current DS program at JLab (HPS, APEX, BDX-MINI)
- Future: BDX, JPOS, μBDX, μPrad, vBDX (CEvNS)
- Rich program with positron beam
- Good use of EOT for complementary secondary beams: LDM, neutrino, muons,
- Necessary infrastructures: new BDX Hall (to be done soon to match MOELLER run time)
- Program staged between NOW and 24 GeV

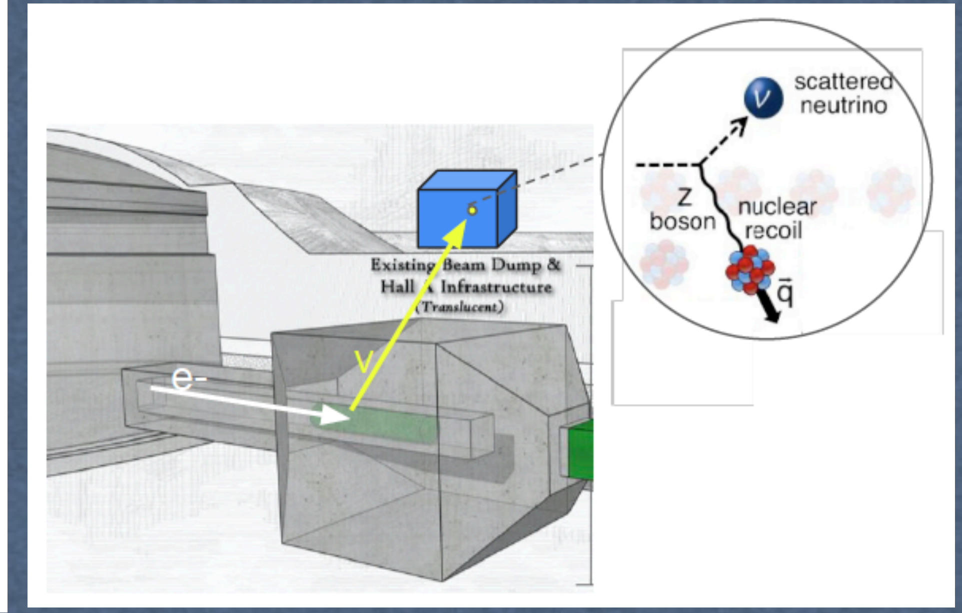


BDX in the upgraded CEBAF era

- CEBAF @ high-lumi
  - No new infrastructures are necessary
  - BDX can take advantage of high-lumi beam immediately
- CEBAF @ 24 GeV
  - New infrastructures could be necessary
  - Beam-related background has to be evaluated
    - new shielding between dump and detector
  - BDX@24GeV reach has to be estimated

BDX R&D
- BDX-PROTO
- Simulations
- BDX-HODO

2014 BDX LOI
2018 BDX APPROVED
2019 DOE-FOA grant
BDX-MINI First LDM measurement
2021 NFS-MRI grant
2022 If start BDX-Hall Construction
BDX Construction
2025 BDX in RUNNING
20xx BDX high-lumi run
20xx BDX@24GeV run
HIGH-LUMI era
24 GeV era



Infrastructures

Ce+BAF : Positron Beams at Jefferson Lab

Joe Grames

Mu and Nu beams using Hall-A Beam Dump

Antonino Fulci

- R&D based on PEPPo (Pol Electrons for Pol Positrons
- Focus on positron source
- positron at LERF: in next 5y >100 nA unpolarized or >10 nA polarized positron beams
- Supported by an LDRD
- JLab Acc fully supportive
- BeamDump secondary beams
- FLUKA simulations (supported by RadCon and Acc)
- Up to 6 GeV Bremm-like muon beams
- 0-50 MeV decay at least (DAR neutrino beam)
- Physics program includes: PRAD with muons, CEvNS , neutron skin in nuclei, Theta_W, …

Conclusions

Host a positron workshop at JLab with goal of determining the level of interest for our three options: GeV, MeV and keV polarized positrons, this could happen in the fall this year. And then in parallel…

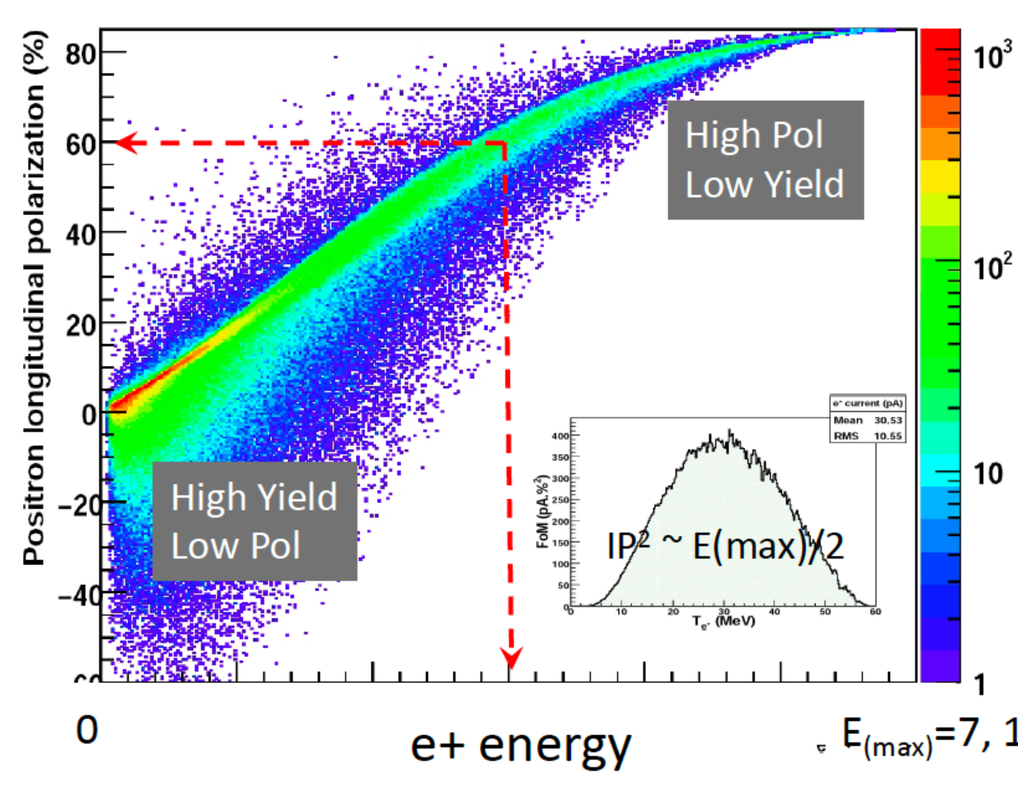
Finish the CEBAF injector upgrade, this frees up labor associated to these projects

After installing the new booster at CEBAF, we move existing CEBAF ¼ CM to the LERF

Install a 350 kV load locked gun at LERF, making 8 MeV polarized electron beam 1 mA

Design and build a 10 kW prototype target, 0.5 Tesla magnet and the e-/e+ beam lines

In five years we make >100 nA positron beams, this means with good beam quality, suitable for acceleration



Conclusion

- Assuming 50uA, 11 GeV electron beam on Hall-A beam dump (10^{22} EOT in 1 year)
- **Muon beam:**
  - expected flux ≈ 10^9 μ/s in the z-direction
  - energy up 6 GeV with a bremsstrahlung-like energy spectrum
  - requires dedicated infrastructures (magnets, drift, …) to tag and measure muon momentum upstream of the BDX shielding
- **Neutrino beam**
  - Expected flux of ≈ $10^{17} \div 10^{18}$ $\nu * y * m^2$ (depending on the location)
  - DAR energy spectrum (0 - 50 MeV, 30% monochromatic @~30MeV)
  - High-energy nu flux (E > 100 MeV) is reduced by a factor ~100
  - The detector can be located perpendicularly to the dump above-the-ground or on the concreate vault surface
- **Work in progress: neutron background**
  - A combination of passive shielding and active/veto should reduce the neutron background to negligible values
  - FLUKA simulations are running for a first assessment
  - Shielding optimization in progress

Infrastructures

Feasibility study for FFA racetracks in the existing CEBAF tunnel to reach the top energy of 22-24 GeV

Alex Bogacz

CEBAF power limits

Jay Benesch

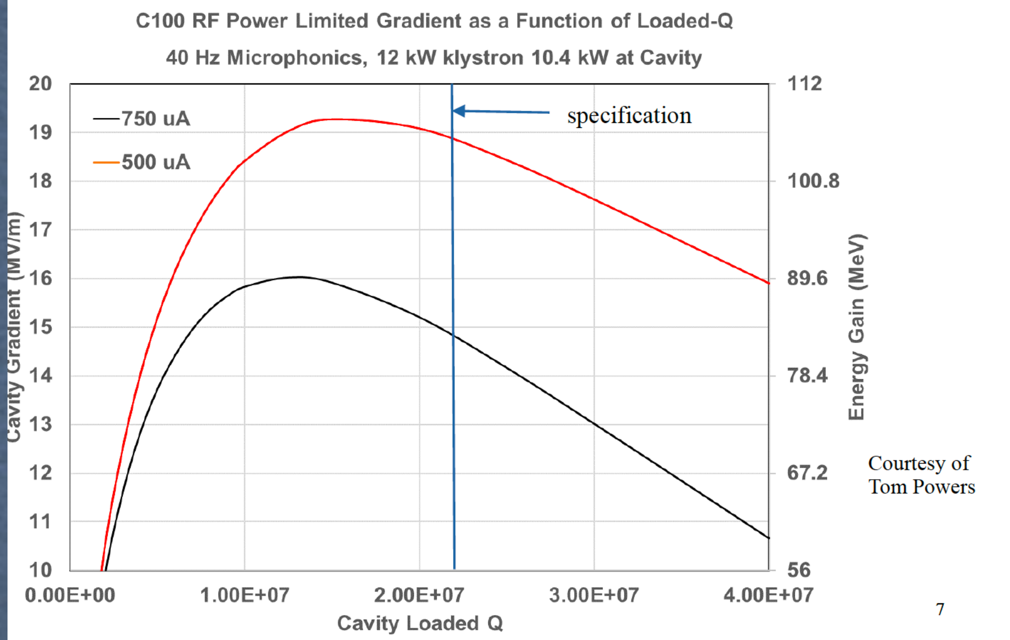
- FFA for JLab at 24 GeV w/o new SRFs
- Total of 11 Pass replacing 1 arc
- injector upgrade (650 MeV)
- Possible option for positrons too
- Staging in two phases (17GeV and 24GeV)
- High intensity (up to 2MW) can be easily handled by current SRFs
- Few modifications to the dumps may be necessary
- 70uA to A and C simultaneously

Overview

- Adiabatic FFA Arc – CBETA-proven architecture
  - Non-scaling FFA based on high-gradient permanent magnets
  - Adiabatic control of betas and dispersion (gradual variation of cells)
- Multi-pass linac optics
  - Periodic triplet lattice for all passes
  - 650 MeV injector upgrade
- Modified CEBAF switchyard with pathlength corrections
- Current baseline: 650 MeV inj + 3-pass CEBAF + 2 × FFA
- Synchrotron radiation impact on beam quality, mitigations
- Positron option
- Summary, Outlook

Summary

- Present Baseline (1.1 GeV per linac):
  - 650 MeV Recirculating Injector (additional three C-90 cryomodules)
  - Recirculate 3 passes with the current CEBAF
  - Additional 8 (4 + 4) passes via two FFAs: **8.3 – 14.7 GeV** and **16.8 – 23.7 GeV**
- Adiabatic FFA arcs configured with compact FODO cells
  - Beta and dispersion matching to the linacs through cell-by-cell variation (length, bend)
  - Open mid-plane permanent magnet design: B-field ≤ **1 T**, Gradient ≤ **47 T/m**
- Multi-pass linac optics: Periodic triplet lattice for all passes
- Synchrotron Radiation impact on beam quality
  - Net transverse emittance dilution (normalized): **60 mm mrad** at 23 GeV, β = 20 m → σ = 150 microns
  - Net natural energy spread: **2×10^{-3}**
  - Net synchrotron radiated energy: **964 MeV**
- Physics topics that can only be explored with energy well above 12 GeV (Hall C)
  - Interpretation of EIC exclusive and semi-inclusive programs, e.g. conventional Rosenbluth LT separations
  - Double Deep Virtual Compton Scattering, Deeply Virtual Meson Production (scaling region)
  - Parity Violation to constrain strange quarks, Tagged Deep Inelastic Scattering



Conclusion

- Documentation and the machine protection system limits derived from it should no longer be an issue within two years.
- Facilities is planning heat removal upgrade from 1.1 MW when funding permits.
- Tests will be performed by end of 2022 to determine the limits of the RF/SRF systems and how they may be mitigated. If the stub tuners work, they will be installed on all input-Q limited cavities as funding permits.
- It is my hope that it will be possible to deliver 70 μA each to Halls A and C at 11 GeV before 2026 in parallel with 25 kW to B and 60 kW to D, 1625 kW total.

Infrastructures

CLAS - CLAS12 - CLAS24

Volker Burkert, Jefferson Lab

Instrumentation for high luminosity upgrade of CLAS12

Annalisa D'Angelo

- Specs from 24 GeV physics case (DVCS, J/Psi, hadron spectroscopy)
- Improvements: 2xLumi, charged PiD (FW and CTR) , TRCK/VTX, lowQ2 (0-deg cal)
- Planned CLAS12 HI-LUMI upgrade (2x)
- R&D and prototyping
- Technology defined (uRwell)
- Option to increase L x10 in the future

Outline:

- Need of the upgrade: CLAS12 performance and physics cases
- History: High-luminosity upgrade task force operation and outcome
- Stage 1 – DC tracking update to obtain x2 CLAS12 luminosity
- Stage 2 – x10 CLAS12 luminosity
- Outlook & conclusions

Summary

- An energy upgrade of JLab to 20+ GeV would open up high impact science not reachable at the currently available 10.6 GeV beam energy. They include:
  - A program related to quark and gluon GPDs and mechanical properties
    - DVCS at small x_B and in a large t-range
    - J/ψ production at threshold in a wide range of x_B and t
    - Time-like Compton scattering in wide kinematic range
  - Spectroscopy involving heavy quarks (c-cbar)
    - Systematics of X, Y, Z states and pentaquarks, discussed on example of $Z_c(3900)$
- The first program could be an extension of the program with CLAS12 with improvements in tracking, vertexing and particle ID.
- The exotic spectroscopy would require a near 0-degree electron tagging spectrometer in the energy range from about 2 to 14 GeV. The concept has been described, but it requires detailed simulations and a realistic layout of the spectrometer magnet and detectors to make a statement about achievable luminosity.
- No cost estimate has been attempted. The Si-pixel tracking detector will be very expensive depending on pixel sizes (prototypes are been developed for EIC).

Summary & Conclusion

- Two stage Luminosity upgrade has been foreseen by JLAB following the outcome of the high-luminosity Task Force:

  I. increase the luminosity by x2 with high reconstruction efficiency
  II. proceed with >x10 increase

- **Phase 1** - DC R1 should be backed or substituted by a faster MPGS
  - μ-Rwell detectors have been identified as the most suited MPGS
  - R&D activity is on-going –both at JLAB and INFN - to identify the best 2D – large scale configuration of μ-Rwell detect to cover R1 region (2 years study + final production)
- **Phase 2** - μCLAS12 / open acceptance configurations require major changes and streaming read-out DAQ electronics

Broader theory questions

- Which properties of the nucleon are described sufficiently well by valence quarks only?
- Which properties of the nucleon can we really measure (e.g., its mechanical properties)?
- To which extent can we trust perturbative calculations? Where does the formalism work and where should it be modified?
- Can we describe a transition to nonpertubative QCD?
- Is lattice QCD able to predict the nonperturbative features of the proton reliably?
- Can we look for physics beyond the Standard Model?

Alessandro Bacchetta
Harut Avagyan
Raphaël Dupré

Nuclei : Higher Energy, Luminosity or Charge ?

The nuclear physics program of JLab is rich

- We have important studies possible on the nuclear structure front
  - **EMC effect : Already very well measured**
  - **Nuclear DVCS : high luminosity and charge asymmetries**
  - **Tagged processes : high luminosity**
- The final state effects in nuclei are equaly worth of study
  - **Hadronization : High energy ? (but need to see 11 GeV before)**
  - **Nuclear TMDs : Likely to need higher energies**
  - **Color transparency : High luminosity**

Adam Szczepaniak
Bryan McKinnon
Gordan Krnjaic
Raffaella De Vita

Hadron spectroscopy at an upgraded JLab

Multi-quark candidates, *XYZP* states, observed mainly in the charmonium spectrum have revolutionised hadron spectroscopy

- observed in reactions involving complicated production and/or decay processes
- interpretation of signal may be difficult due to kinematic effects (resonance mimic?)

Existence of these states would be confirmed via observation in photo- or electro-production and yield more information on their nature

- at 24 GeV many states with charmonium content are within kinematic reach
- electron-proton scattering leads to generation of all I, J^{PC} quantum numbers
- higher energy (~24 GeV), (quasi-real) photoproduction is especially appealing since many of the *XYZP* states could be produced directly and observed decaying to relatively simple final states (eliminating some of the kinematical effects and resonance mimicry)
- utilise polarisation of beam and target to achieve a precise separation of the various production mechanisms (not possible at hadron colliders)
- scan centre-of-mass energies by detecting the scattered electron at different momenta (beam remains at the nominal energy)

Photoproduction cross sections for these states estimated to be of the order of O(1 nb) for photon energies $E\gamma \sim 24$ GeV, widths O(100 MeV)

- requires large acceptance, high-luminosity, good momentum and vertex resolution
- ~24 GeV with high-luminosity more efficient in producing *X* and *Z* states (*Y* states benefit from even higher energies due to diffractive production)
- "It is clearly a great help to detect (tag) the scattered electrons with momentum in the range 0 - 14 GeV below 1 degree" - Zero-degree energy tagging system

Is the hadron spectroscopy programme sufficiently unique and complementary to make a strong case?

J-FUTURE workshop Summary

- Many thanks to presenters, discussions panelists (and all attendees)!
- We investigated opportunities in three main directions + necessary infrastructures
  - 1) Nucleon/nuclei structure via DIS, SIDIS, EXCLUSIVE reactions
  - 2) Hadron spectrum via (semi-)exclusive (exotic) MESON and BARYON production
  - 3) Physics beyond hadronic interactions: Light Dark Matter, muon and neutrino beams
  - 4) infrastructures - DETECTORS and ACC - POSITRON, HI-LUMI, HI-ENERGY JLab upgrades
- Many ideas were presented as an extension of the current JLab program or as a unique option at an upgraded CEBAF/JLAB
- Two dedicated discussion sessions were not enough to accomodate all thoughts and comments

★ **Strong interest in JLab upgrades by USERS and lab management**

★ **Solid ground for a sound proposal for JLab upgrade(s)**

… but a long way to go

- Define priorities in the physics program (golden channels vs comprehensive physics program)
- Define inputs to stage the three possible different upgrades (high energy, high lumi, positrons)
- Define a strategy to cope with the EIC competition: identify complementarities
- Define a work plan to match the next NSAC Long Range Plan timeline

- We propose to create four WGs (3 physics + 1 technical)
- Coordinate the USER activity in the next few months
- Coordinate with JLab topical workshops an acc studies planned for the next few months
- Prepare the ground and four summary reports for the ECT* workshop in September 26-30 2022
- Contribute to the white paper in the fall 2022

Alessandro Pilloni
Eric Voutier
Marco Battaglieri

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

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