SoLID Director's Review

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SoLID Director's Review
February 9-10, 2021

Review Process and Charge

A Director's Review was organized February 9-10, 2021 by Jefferson Lab management to assess the readiness of the SoLID collaboration for a DOE Science Review scheduled for March 8-10, 2021. The Review Panel consisted of: Elke Aschenauer (BNL), Ayres Freitas (U. Pittsburgh), Geoff Greene (UT Knoxville and ORNL), Wolfgang Lorenzon (U. Michigan), Anna Stasto (Penn State U), and Feng Yuan (LBNL).

The Charge to the Review Panel was as follows:
The panel is asked to evaluate and comment on any relevant aspects of the proposed scientific program for SoLID. Please consider the following charge elements in this review:

1. The significance of scientific questions identified by the SoLID Collaboration.
2. The impact of the planned scientific program on the advancement of nuclear physics in the context of current and planned world-wide capabilities, including the US Electron Ion Collider.
3. The new experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.
4. The feasibility of the approach or method presented to carry out the proposed scientific program and the likelihood that significant results can be obtained in the first three years of detector operations.

In addition, the panel is asked to consider the impact, if any, of SoLID implementation on the ongoing scientific program at TJNAF in any of the charge elements above.

SIDIS Program

1. The significance of scientific questions identified by the SoLID Collaboration.
Yes, the collaboration identified scientific questions of substantial importance.

Findings:

- The kinematic coverage in Q^2 and p_T are suitable to apply TMD models/factorization to the data.
- The kinematic coverage is well suited for the Tensor charge as it is a valence distribution and has therefore no gluon contribution from small-x.

Comments:

- The collaboration needs to better articulate what science requirements drive the luminosity and binning to guarantee the scientific impact.

- There is also a unique opportunity to study non-perturbative physics, e.g., the target fragmentation. This should be emphasized more.

Recommendations:

- None

2. **The impact of the planned scientific program on the advancement of nuclear physics in the context of current and planned worldwide capabilities, including the US Electron Ion Collider.**
   Yes, but the comparison to EIC is not yet adequately addressed.

   Findings:

   - The SoLID Collaboration did comprehensive comparative studies with the other ongoing JLab programs: SOLID vs CLAS12 and SBS in Hall A.
   - Comparison to EIC in the x-Q2 kinematics SoLID in general is at lower Q^2 at the same x, because of the larger kinematic reach of EIC it will constrain to significantly lower x, accessing sea-quarks and gluons.
   - Rigorous theoretical studies on the comparisons with the EIC program still need to be performed.

   Comments:

   - As the TMDs extracted from experiments are not directly connected to the confined motion of quarks in nucleons, and because parton shower effects dilute the information, they crucially depend on Q^2. At at the same x (valence region), SoLID and EIC have totally different Q^2 as a result, the parton shower effects (QCD evolution) can be systematically studied. This complementarity should be highlighted and more quantitative studied. An example study could be to investigate how much the asymmetry is smeared due to parton shower effects in SoLID. This result can be contrasted to what is expected at the EIC.
   - Ultimately, a study should be conducted using the EIC-pseudo data including EIC systematic uncertainties in the same way as SoLID, to study the impact of the data sets on the same footing. For this, one should use the same theoretical model and study what one would get on impact extracting TMDs using the EIC data, using the SoLID data and both.
   - SoLID should be prepared to answer if the upcoming COMPASS runs are posing a competition.

   Recommendations:

   - The study discussed in the first comment above should be done for the DOE review.

3. **The new experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.**
   Yes, if the recommendations get addressed before the DOE review.

Findings:

- We acknowledge there are synergies between technical developments for other programs at JLab and in between the different science pillars of SoLID.

Comments:

- From the presentations it was not possible to understand how far the R&D on the different detectors has progressed to ensure the chosen technologies are able to perform to the physics requirements, especially at the occupancy expected due to the high luminosity of 10^{37} – 10^{39} $cm^{-2}s^{-1}$
- It has not been clearly articulated, which additional theoretical progress is required over the next 5 years to interpret the data to really extract the 3d momentum structure of nucleons. This can be important to ensure the needed theoretical efforts continue.
- The SoLID collaboration needs to be able to clearly articulate what the required minimum integrated luminosity is to ensure science impact.

Recommendations:

- Articulate in all the experimental science talks clearly the physics requirements for the detector.
- Develop a clear R&D plan beyond the pre-project R&D, which is needed to achieve the physics performance by the detector.
- The SoLID collaboration should clearly articulate the timescale SoLID needs to be realized due to competing experiments so that the risk is minimized that SoLID science impact is decreased or lost.

4. **The feasibility of the approach or method presented to carry out the proposed scientific program and the likelihood that significant results can be obtained in the first three years of detector operations.**
No, as originally presented.

Findings:

- SIDIS will be among the first to run during a three year program. A plan exists to realize this, based on (a) synergy between the exp. and theory efforts; (b) experiences to analyze the data right from the start.
- No particular technical challenges to realize the SIDIS program have been seen.

Comments:

- The first three-year program was not clearly presented. The answer to the HW question described the program in the first 3 years, but did not fully give the underlying considerations which led to the program.

- Times needed to switch between the programs need to be better described and the considerations which result in the order the key science programs are run need to be clearly described.

Recommendations:

- Develop a clearer presentation of the first three-year science program and the reasoning for the optimization.

J/Psi Experiment

1. **The significance of scientific questions identified by the SoLID Collaboration.**

Findings:

- The SoLID J/ψ program has identified several science questions that are enabled by the J/ψ measurement at threshold. These include the emergence and origin of the proton mass and the hadron masses in general, the strength of the interaction between the quarkonium and the nuclei (the color Van der Waals force), existence of the nuclear bound quarkonium state and the existence of the pentaquarks.
- Among those four, the theory talk addressed only the question regarding the origin of the proton mass.
- The experimental talk addressed primarily the origin of the proton mass and the charm pentaquark search.

Comments:

- Both theory and experimental talks presented clear and strong motivation for the proposed scientific questions, in particular for the origin of the proton mass.
- All the scientific questions are very important and of great significance. Among the four scientific questions, the origin of the proton mass is the best motivated and appears the most significant and fundamental to the understanding of the strong force.

Recommendations:

- None

2. **The impact of the planned scientific program on the advancement of nuclear physics in the context of current and planned world-wide capabilities, including the US Electron Ion Collider.**

Findings:

- The impact of the planned J/ψ measurement at threshold is strong for nuclear and particle physics. There is good complementarity between SoLID and the

EIC, since they cover different kinematic regimes. Thanks to its lower center-of-mass energy than the EIC, SoLID is better suited for the measurement of J/ψ at threshold. This measurement is significantly harder with the EIC than with SoLID, while measurements of the Upsilon are more ideally suited for the EIC.

- The charm pentaquark search prospect was only discussed briefly in the experimental talk.
- The SoLID J/ψ program compares to CLAS12 favorably. Photoproduction in SoLID will have higher statistics after 50 days of running than 9 years at CLAS12. Also, much better statistics for electroproduction is expected at SoLID.

Comments:

- It would be beneficial to perform more studies on the possibilities of the pentaquark searches at SoLID in light of the absence of evidence for the LHCb pentaquark in a recent measurement by GlueX.
- Elastic vector meson production in photoproduction can also be accessed in the ultra-peripheral collisions in proton-ion scattering, which were performed at RHIC and LHC. These measurements are performed at higher photon-proton energy W Thus there seems to be good complementarity for SoLID, and an advantage over the UPC to perform the threshold measurement.

Recommendations:

- A comparison between the SoLID and UPC measurements should be performed to better assess their differences

3. The new experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.

Findings:

- The theoretical efforts for the SoLID J/ψ program to accomplish the proposed scientific program have made steady progress and continue to do so.
- There is great recent theoretical activity in this area, indicating significant interest in the scientific questions to be addressed by SoLID.
- Work on radiative corrections was incorporated in the physics program.
- The experimental efforts needed to accomplish the proposed scientific program have not been clearly presented.

Comments:

- Estimates for sources and magnitude of systematic errors were presented. It would be beneficial to have more detailed studies showing that the target 5% error is feasible.
- Detailed studies of the radiative corrections still need to be evaluated in the context of the J/ψ measurements.
- Present a plan that outlines the R&D efforts needed beyond the existing pre-R&D to achieve the science goals.

Recommendations:

- None

4. **The feasibility of the approach or method presented to carry out the proposed scientific program and the likelihood that significant results can be obtained in the first three years of detector operations.**

Findings:

- Estimates for systematic errors were presented. The acceptance was the largest contributor to the systematic error, while the cross section contributes at the 5% level
- The physics program at SoLID can be compared and calibrated with Hall C.
- Prospects of measurements of other states: ω,ρ,φ,η were presented, demonstrating good capabilities of the experiment.
- Simulations on the mass, energy and momentum transfer were presented with good resolution of 0.14 GeV^2 in t.
- A very good range of momentum transfer t is expected, which is necessary for a high precision extraction of the slope.
- Studies of the uncertainty on the parameter b (related to trace anomaly) as a function of luminosity were presented.
- Large statistics of SoLID is required to obtain precise t-distributions for each bin of photon energy. This is critical for the extraction of the t-slope slope as a function of energy, and to pin down the exact functional dependence of the t-slope.
- J/ψ measurements are scheduled to be performed at the beginning of the second year of running.

Comments:

- More detailed studies on the systematic uncertainties are needed to ensure the desired accuracy of the measurement can be achieved.
- Impact of detector resolution of scattered electrons, vector meson resolution and radiative effects need more studies.
- It would be useful to better investigate the impact of luminosity and t-resolution on the limits of the b parameter.
- There is good prospect of obtaining the first physics results on J/ψ measurements within the first three years of running.

Recommendations:

- None

PVDIS Program

1. The significance of scientific questions identified by the SoLID Collaboration.

Findings:

- The case for PVDIS at SoLID was clearly delineated. The use of an iso-scalar deuterium target slows for a precise measurement of the parity-violating coupling combination ($2C_{2u}$-C_{2d}) that is difficult to access otherwise. Models of leptophobic Z' bosons can lead to a deviation in these couplings while being in agreement with all other existing constraints.
- Measurement of the parity-violating asymmetry at SoLID can also be used to extract information about charge symmetry violation of quarks in nuclei, which sheds light on fundamental aspects of QCD and could help to resolve the long-standing NuTeV discrepancy.

Comments:

- We suggest that the collaboration update their proposal document to explain the physics case more clearly, including some material that was shown in the presentations, including: definitions of R_{CSV} in Fig.26, a(x) in section 2.3.5, and Lambda in Fig.25; show correlations for the fit to eq.(9) and explain the assumptions about C_{1q} there; update Fig.28 with improved nuclear error bands; show the binning for Fig.29; explain that the efficiency in Fig.162 includes the effect of the baffles.

Recommendations:

- Carry out an analysis which computations of radiative corrections (or other theoretical input) are needed to reduce the theory uncertainty to 0.2% as assumed in the proposal.

- It is not expected that these theory calculations are already available at this stage of the R&D process, but the collaboration should prepare a clear roadmap of the required steps to accomplish the theory precision target for the DOE review.

2. The impact of the planned scientific program on the advancement of *(nuclear)* physics in the context of current and planned world-wide capabilities, including the US Electron Ion Collider.

Findings:

- The ability to precisely measure ($2C_{2u}$-C_{2d}) allows SoLID to access BSM physics that is complementary to P2 and LHC. The combination of these experiments provides improved coverage for searching for new physics (such a new gauge bosons, 4-fermion contact interactions or modifications of the running of the weak coupling) compared to any single experiment.
- The results of SoLID can also be interpreted as a measurement of the running of the weak mixing angle. Here, SoLID covers a running scale that sits in between the low scales accessible to P2 and MOLLER and the higher scales accessible at EIC. If a deviation from the SM prediction of the running is observed, SoLID can help to pin down the mass/energy scale of the new physics responsible for it.

Comments:

- We suggest that the collaboration include plots in their proposal document that show the complementarity with LHC (which were shown in the presentation by Erler). It should be clarified what scenario is assumed for LHC (amount of luminosity, combination of ATLAS+CMS, etc.), as well as the concrete definition of the different operations (or cite a reference that clarifies this).

Recommendations:

- None

3. The new experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.

Findings:

- The dominant anticipated systematic uncertainty (0.4%) arises from polarimetry. Attaining this accuracy will require an extension of the state of the art in electron polarimetry.
- A plan for the continuous marginal refinement of polarimetry technology was presented. This includes substantial effort for MOLLER.
- Most of the PVDIS subsystems are based on capabilities that appear to be within the state of the art or require only minimal extension.

Comments:

- The PVDIS team are to be commended for a very clear and comprehensive overview of the proposed experimental apparatus.

- The PVDIS team is broadly experienced in this type of work and appears capable of handling a project of this magnitude. However, the committee was unable to assess whether there will, in fact, be adequate manpower given the competing demands of other experimental efforts as well as EIC development.
- Attaining the required polarimetry sensitivity will be a challenge, but it seems likely that the continuing Hall A & C efforts will provide the requisite capability in time for PVDIS.

Recommendations:

- None

4. The feasibility of the approach or method presented to carry out the proposed scientific program and the likelihood that significant results can be obtained in the first three years of detector operations.

Findings:

- SoLID PVDIS presented a thorough overview of an apparatus based on the straightforward extension of established technology.
- The proposed schedule foresees initial operations of the PVDIS in Q2 of 2032 with a total time on the beam line of 2 years.

Comments:

- Like all PNC experiments, SoLID PVDIS presents a significant technical challenge. Nonetheless, the design appears to be relatively low risk and it is likely to result in an important scientific result.
- Due to beam line scheduling, SoLID PVDIS is not anticipated to have obtained any run data in the first 3 years of detector operations.

Recommendations:

- None

General Comments

- Expeditious assembly and testing of the SoLID apparatus requires extensive preparatory work in the proposed Test Lab Hi Bay Annex or equivalent. While there is considerable optimism about the prospects for the Test Lab Hi Bay Annex, the current absence of adequate assembly space is a concern for all SoLID activities.

Remarks on Improvements for DOE Science Review

- The SoLID collaboration should limit the overlap between the theory and experimental talk on the different key science programs.
- The speakers should rehearse their talks and leave time after each talk for questions.
- The talks should clearly align with the Charge questions and maybe even explicitly put on the slides what Charge question is being addressed.
- All three theory talks were very well prepared. They gave a very nice overview and motivation for the scientific questions.
- The experimental talks gave good overview of the SoLID capabilities, though they could have been better structured to address the Charges more directly (particularly for the SIDIS and J/ψ topics).
- The collaboration made great effort in answering the Homework questions within a very short time. They provided very comprehensive answers to all questions. Collaboration is encouraged to include the Homework answers in their upcoming presentation for the DOE Science Review. At the DOE review the collaboration should try to give more concise answers to Homework questions.

Agenda

Director's Review of SoLID
Virtual (Bluejeans)
February 9-10, 2021

Tuesday, February 9

10:00am	Executive Session	
10:30am	Status and Overview of SoLID	Jian-ping Chen
11:30am	SIDIS Theory	Jianwei Qiu
12:10pm	SoLID SIDIS Program	Haiyan Gao
1:10pm	SIDIS Discussion	
1:40pm	Lunch Break	
2:40pm	Proton Mass and Heavy Quark Production	Xiangdong Ji
3:20pm	SoLID J/Psi Program	Zein-Eddine Meziani
4:20pm	J/Psi Discussion	
4:50pm	Executive Session	
5:40pm	Questions / Homework Assignments	
6:00pm	Adjourn	

Wednesday, February 10

10:00am	Executive Session / Homework Answers	
11:00am	PVDIS Theory	Jens Erler
11:40am	SoLID PVDIS Program	Paul Souder
12:40pm	PVDIS Discussion	
1:10pm	Lunch Break	
2:10pm	SoLID in the JLab Program	Rolf Ent
2:30pm	Executive Session	
5:30pm	Closeout	
6:00pm	End of the Review	