DUNE Calibration and Cryogenic Instrumentation Consortium (CALCI)
Initial Design Review of the Ionisation Laser Calibration system

Question from Committee, Sep. 17

September 17, 2020
V 1.0

Q1) Which aspects of the integration are of most concern? Could you describe how addressing these concerns would help the project?

Many aspects of integration will need to be addressed. Below is our top list of items where we can benefit from more active support:

1. **Impact of cool down and cryogenics environment on the system (location, straightness etc.):** We need to get the requirements and parameters for testing from detector mechanical, cryogenic and ProtoDUNE experts. For example, understanding the cool down effects will confirm if it is really enough to cut through 3 FC profiles (as we are planning) and ensure the FC openings are centered below our calibration port.
2. Finalizing the PD-II design ensuring calibration fits into the plans: We need to be part of the process towards finalizing the PD-II final design. Detector integration engineers and our engineers need to work closely to ensure calibration related needs and requirements are taken into account when finalizing the PD-II design.
3. **Finalize assignment of ports for IoLaser:** A lot of the design aspects hinges on decision on ports (e.g. location of the laser box and stand; at what height the beam needs to exit the laser box and location of the top warm mirror; can we implement one laser serving two periscopes? How do we get the power to the laser? Installation aspects etc.).
4. **FC penetrations:** (this is strongly related to 3). Finalizing ports will allow HV experts to move forward with necessary simulations and finalize FC profiles/supports production plans.
5. **DAQ and Slow Controls:** As pointed out in Nuno's talk, DAQ/SC itself is going through significant changes for PD-II and integrating the laser into that poses an added challenge especially because this is the first time this is implemented.
6. **Power, Electrical and Grounding:** As was pointed out, ProtoDUNE and DUNE will have distinct challenges implementing these aspects and we need to actively pursue the proposed plans and finalize details. This will allow us to understand if the proposed design works or if we need to look for alternative solutions for arrangement of the laser system. We are thankful for the support offered from technical coordination on this and will evaluate in the coming weeks if we need further support.
7. **Safety:** Class-IV laser involves critical safety requirements and the challenges are different for ProtoDUNE and DUNE. This has the potential to impact our proposed designs e.g. placement of the system on the cryostat, more design changes to ensure safety, access and controls, and so

on. Getting safety experts involved (especially for ProtoDUNE) will be extremely critical at this point.

Q2) Which items in the schedule would you allow to expand if the end-date were postponed by a few (e.g., 5 months).

Q5) Is the time for design and acquisition of the testing infrastructure included in the schedule?

We are answering questions 2 and 5 together as they both relate to the schedule.

Response to Q2: Without a doubt, given the extensive testing that needs to be done both in warm and cold, we will extend the overall time assigned to design and procure infrastructure and perform the tests.

The next items would be procurement and fabrication acknowledging the long lead times due to COVID-19. However, given our early start on these items, we are comparatively less concerned.

Response to Q5: It wasn't explicitly included in the schedule shown.

To address both of these questions, we have taken a first stab at updating the IoLaser schedule for PD-II assuming a 5 month delay in the overall start of the detector. See table 1 below. All the cells highlighted in yellow are new/updated.

We have increased the overall IoLaser procurement and fabrication time (since we had already considered this before) and we have increased the QA/QC testing period by 3 months. We have added two new milestones for the two LANL labs being ready and operational and we have added two new activities in the schedule to show the time for design and acquisition of the infrastructure needed for the cryogenics lab.

We hope this provides a first response to this question and we will further refine this schedule in the future as the PD-II schedule is more firmly defined.

S. No.	Activity	Start Date (old)	End Date (Old)	Date (New)	End Date (New)	Comments
A1	ProtoDUNE-SP-II IoLaser design work (phase 1)	12/1/19	7/30/20	12/1/19	7/30/20	This is the heavy initial design work that brings us to the 30% design review
A2	Purchase Class-IV UV laser & laser box optics for ProtoDUNE-SP-II	3/1/20	11/30/20	3/1/20	1/31/20	
M1	**Calibration Scope review workshop**	**5/11/20**	**5/31/20**	**5/11/20**	**5/31/20**	**CALCI Scope review workshop**
A3	Io Laser Design work towards ProtoDUNE-SP-II Preliminary Design Review (PDR) (phase 2)	8/1/20	1/30/21	8/1/20	4/30/21	
A4	Procure laser system components	8/1/20	4/30/21	8/1/20	5/31/21	
M2	**ProtoDUNE-SP-II IoLaser Initial Design Review**	**9/16/20**	**9/18/20**	**9/16/20**	**9/18/20**	**Initial design review (more like 30% design review)**
S1	ProtoDUNE-SP-I Disassembly TCO drift volume	10/1/20	11/30/20	10/1/20	11/30/20	global ProtoDUNE-SP-II milestone (UNCHANGED)
A5	Procure custom flanges, electronics board and DAQ components	12/1/20	4/30/21	10/1/20	5/31/21	
A6	Define design and infrastructure needs for QA/QC tests			10/1/20	11/30/20	
S2	Open TCO ProtoDUNE-SP-I	11/1/20	12/31/20	11/1/20	12/31/20	global ProtoDUNE-SP-II milestone (UNCHANGED)
A7	Start design and procurement of infrastructure for QA/QC tests			11/1/20	4/30/21	
M3	**LANL laser lab ready & operational**			**11/15/20**	**11/15/20**	**We are aiming for this for Oct. 2020 but assuming some delays due to COVID-19**
S3	Remove ProtoDUNE-SP-I TPC	1/1/21	3/31/21	1/1/21	3/31/21	global ProtoDUNE-SP-II milestone (UNCHANGED)
A8	Fabrication & Assmebly of the laser system	3/1/21	8/30/21	3/1/21	10/31/21	overlap with A8 since we expect some tests can be done in parallel e.g. post-fabrication component testing can start as soon as fabricated samples are available
A9	Engineering/design work during procurement, fabrication, testing, integration, and installation (phase 3)	1/1/21	12/31/21	5/1/21	5/31/22	
M4	**LANL cryogenics testing platform ready & operational**			**5/31/21**	**5/31/21**	**we are aiming for end of March 2021 but assuming here some COVID-19 delays since facility and safety approvals are involved**
A10	Test IoLaser components/system in warm/cold	7/1/21	9/30/21	6/1/21	12/31/21	warm and cold laser periscope tests; Prepare for shipping to CERN after testing
M5	**ProtoDUNE-SP-II IoLaser Design PDR**	**1/31/21**	**1/31/21**	**7/14/21**	**7/16/21**	**60% design review; assumed dates, to be finalized (CHANGED)**
S4	ProtoDUNE-SP Cryostat accessible	4/1/21	8/31/21	9/1/21	1/31/22	global ProtoDUNE-SP-II milestone (CHANGED)
S5	Install ProtoDUNE-SP-2 Detector	8/1/21	12/31/21	1/1/22	5/31/22	global ProtoDUNE-SP-II milestone (CHANGED)
M6	**Laser Box unit(s) arrive at CERN**	**7/31/21**	**7/31/21**	**1/14/22**	**1/14/22**	**Laser boxes are installed first on the cryostat and arrive at the site first; (AVOIDING HOLIDAYS)**
A11	Assemble & Install laser boxes on Cryostat and test alignment	8/1/21	8/15/21	1/15/22	1/31/22	Labor estimated as 4 people (scientist/postdoc) onsite for 3 weeks, about 480 hours; there is flexibility to combine the laser box installation with periscope if needed **(AVOIDING HOLIDAYS)**
M7	**Laser periscope units arrive at CERN**	**10/30/21**	**10/30/21**	**3/31/22**	**3/31/22**	**Laser periscopes are installed after FC modules are installed;**
A12	Assemble & Install Laser periscopes into the detector & test alignment	11/1/21	11/20/21	4/1/22	4/30/22	~3 weeks of installation time assumed for installation and alignment setup; Labor estimated as 5 people (scientist/postdoc) onsite for 4 weeks, about 800 hours;
S6	Close ProtoDUNE-SP cryostat TCO	1/1/22	1/31/22	6/1/22	6/30/22	global ProtoDUNE-SP-II milestone (CHANGED)
A13	Engineering support for IoLaser during commissioning and data taking (phase 4)	1/1/22	6/30/22	6/1/22	11/30/22	
S7	Fill ProtoDUNE-SP-II Detector	2/1/22	4/30/22	7/1/22	9/30/22	global ProtoDUNE-SP-II milestone (CHANGED)
A14	Design validation and data analaysis for IoLaser in ProtoDUNE-SP-II	5/1/22	12/1/23	10/1/22	3/31/23	Labor estimated at 6 people (scientist/postdoc/graduate student) over 1.5 years

Table 1: Updated IoLaser schedule for PD-II. Both old and new dates are shown for comparison. Cells in yellow indicate new/updated information.

Q3) When would you be able to present a list of infrastructure and equipment needed for the QA/QC program?

As noted during the QA/QC talk, this is the next high priority item on our list since we would like to start procurement as soon as possible in order to meet the schedule. We are aiming to have such a detailed list prepared within the next two months or sooner if possible. However, the preparation of the list and procurement doesn't need to be sequential. As the list matures over the next few weeks, we will in parallel start procurement of items that are clearly identified as needed as part of the tests planned e.g. candidate cold and periscope cameras, targets to place inside dewar etc. The primary goal is to be ready for testing by early next year e.g. March or April 2021 assuming the testing platform will become operational by that time.

Q4) What infrastructure (e.g., targets, lighting, paddle to generate liquid flow) is proposed for installation in the test dewar?

Please note that the below is by no means a complete list, just an initial draft based on our current thinking. We can provide a more detailed response after the review (see our response to Q3). (The list below doesn't include the core laser system components e.g. periscope assembly, flanges etc. or the dewar itself as it is assumed those would be available.)

Infrastructure needed:

1. ***Targets and PIN diodes.*** In order to test whether we are pointing the beam in the right direction, we need to be able to detect light from both the UV and the visible alignment laser. A few pin diodes can achieve that and also test the PIN diode LBLS method. We also plan to install targets that reflect/scatter visible light and that fluoresce with UV light, to be imaged by cameras.
2. **Cold cameras & lighting.** These have multi-purposes: to add during installation, to check for obstacles when lowering the periscope, and to image objects inside the cryostat for the various tests -- some aimed at "FC opening", some at targets.
3. **Candidate periscope camera(s) and PMT(s)**. These will be part of the periscope assembly and be used for their stated purpose -- aiding in periscope extension, and beam alignment. Candidate options will be explored to finalize models.
4. **Inclinometers.** Due to the small size of the cryostat, less variations than in DUNE are expected. Still, installing them here allows a test of their readout and one can introduce intentional tilts.
5. **Temperature sensors.** For filling operations and cryostat safety checks.
6. **Paddle with a motor to generate liquid flow.** In order to check for possible tilts of the periscope. The motor must be cryo-rated, and the paddle should be placed closer to the bottom of the periscope to maximize the torque.
7. **Level sensors.** Only a simple sensor with rough precision is enough to check that periscope is immersed at the level expected. Probably a capacitive meter.
8. **Pressure sensors.** Monitoring the pressure in the ullage is useful during fill and to ensure stability in operations.
9. **Gas analyzer.** Since we'd like to monitor the scintillation light via the top PMT, we should check that the purity is reasonable. We could use O2 analyzers only (the least expensive), and use O2 levels as a proxy for N2 and H2O.
10. **N2, O2, H2O filters** (e.g. Oxisorb, Trigon, Zeolite, Hydrosorb)

Integration tests

11. **PDS samples.** To test the impact of laser on PDS with realistic light levels and realistic cryo conditions.
12. **FC penetration mockup.** In order to test the retraction mechanism, we plan to install a replica of the top FC opening with the real size (18x18 cm). A simple aluminum frame should be enough.
13. **PEEK samples** to understand response in LAr.
14. **Detector component samples** e.g. FC profile or CPA, to characterize reflection of laser light in LAr and possibly look for bubbles.

How exactly we will place and attach these devices in the test dewar will require additional infrastructure, which needs to be defined yet.

Q6) Which requirements do you consider the most important to demonstrate in protoDUNE?

The ProtoDUNE-II tests will be the first time calibration hardware prototypes will be implemented and tested for the DUNE FD and so we deem all aspects of the system are very important to test thoroughly. But, the following would be our top priorities.

1. **Technical**
    a. FC penetration (critical requirement to achieve needed coverage)
    b. Top-FC periscope Retraction (critical design feature)
    c. End-wall dual rotary concept (new concept; demonstration important to ensure the capability of achieving two-origin tracks in the end wall regions of the DUNE FD)
    d. Split periscope design (important to test this in view of DUNE installation requirements)
    e. Alignment target and cameras (all new design features implemented to mitigate alignment difficulties and ensure visual clearance checks for FC penetration)
    f. Laser system arrangement (also related to electrical, grounding & shielding)
    g. LBLS mirror concept (new concept; electrically passive system)
    h. LBLS pin diode interfaces with FC and cable routing schemes (ensure HV safety and low noise)
2. **Operations**
    a. Ability to fine tune intensity to avoid self-focusing effects
    b. Stability of the "charge-vs-length-along-track" profile
    c. Functionality of the Calibration/DAQ Interface Board
    d. Testing the functionality of automation software to control complex track direction sequences
3. **Physics**
    a. Single-beam coverage of detector components (APA, CPA RP) to detect deflections
    b. Precision of drift velocity/E-field measurement with
        i. two-origin track analysis
        ii. combination of single track with cosmics
    c. Capability of doing charge-based measurements
    d. Compare laser measurement results to cosmics and perform cross checks

Q7) What is needed to complete the set of technical requirements to be submitted to the EB/TB?

Please note that the requirements we presented are for IoLaser and LBLS systems only. For EB and TB approval, we need to understand what is more efficient, we take some more time and include requirements from all other systems and then submit all together on behalf of CALCI for approval from EB and TB. Or, if EB/TB prefers, we move forward with what we have, we can certainly do that but with the understanding that we will seek approval at a later time with requirements from other systems. Perhaps the former approach is preferred. Also, developing requirements for other systems at the level of IoLaser+LBLS systems will take time and effort from other sub-system leads but given the PD-II schedule and that all those systems will start design reviews some time soon in view of PD-II, we can certainly converge on this in the next few weeks and submit as a whole. We will follow up with EB/TB regarding this.

Speaking of IoLaser only:

- For EB-held, we think we are good to go for now (again with the understanding that if the scope is revised, we may have to revise these requirements).
- For TB-held, in light of this review and feedback received, we would like to take some time to see if we need to add or modify anything before submitting them for approval from TB. But, this can be done shortly after receiving full feedback from the committee. As part of the process, we would also like to discuss this at the consortium level before submitting. If we need to provide a timeline, this should be possible in a month or so.
- For Cons-held, similar to TB-held, we would like to take some time to see if anything needs changing and update them accordingly before posting. We are thinking to develop an approval process at the consortium-level so these can be version controlled to some level for cleaner bookkeeping purposes.