SP PHOTON DETECTION CONSORTIUM

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30% READINESS REVIEW

NOVEMBER 13, 2018

UNICAMP

FAPESP

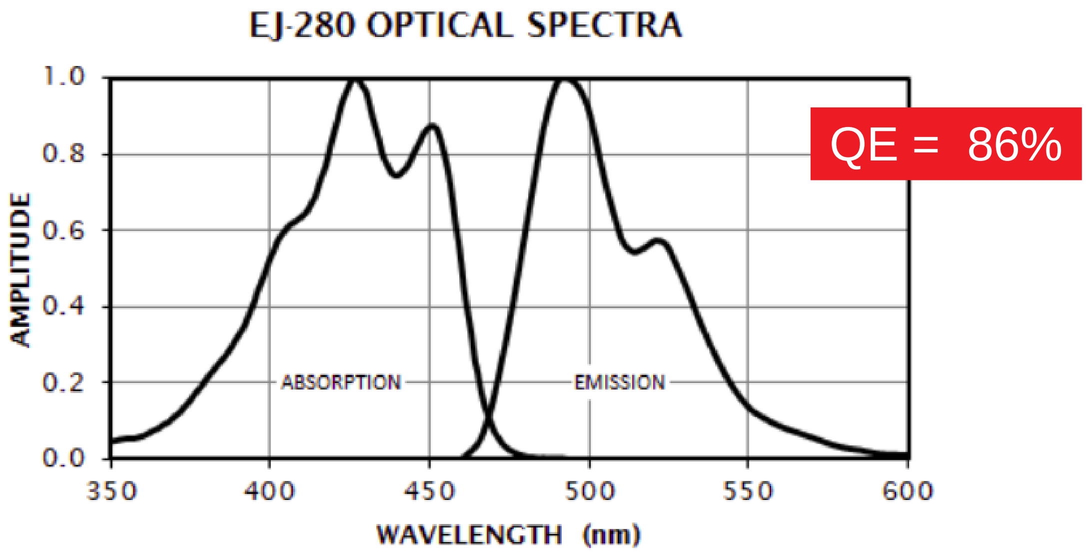
CNPq
Conselho Nacional de Desenvolvimento
Científico e Tecnológico

X-ARAPUCA simulations

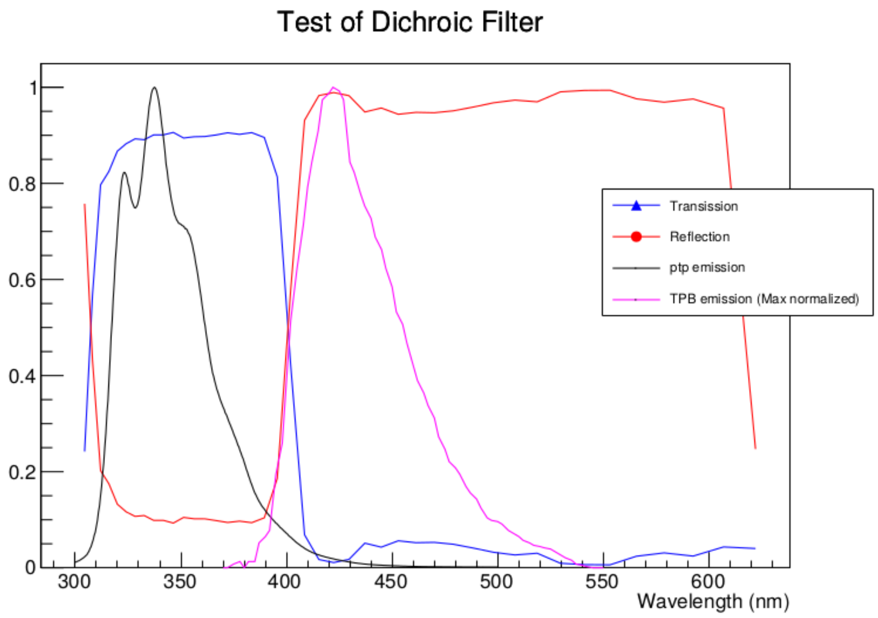
- We don’t have a complete simulation of the X-ARAPUCA supercell baseline design yet
- Two groups are working on it, one in Brazil (Laura Paulucci - UFABC, Franciole Marinho – UFSCAR, Ana Machado - UNICAMP) and one in the US (Denver Whittington and Kyle Spurgeon - Syracuse)
- Syracuse simulation is derived from guiding bar one
- Brazilian simulation is derived from the ARAPUCA one
- Preliminary results available but not for the exact geometry of the supercell

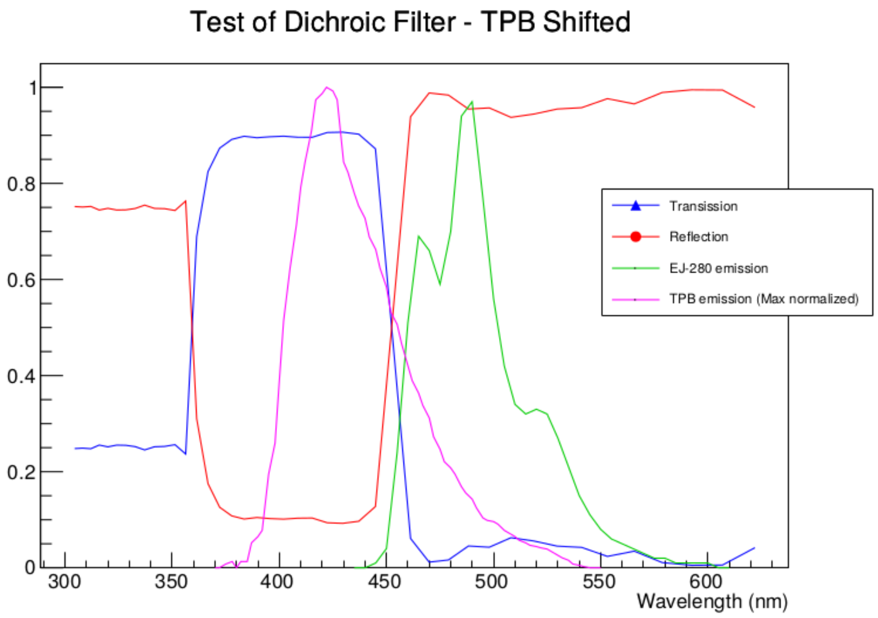
Syracuse simulation

- Simulation of the double shift light guide with two different detector geometries with and without dichroic filters so as to quantify the dichroic filters effects.
- 6mm SensL C-series SiPMs were simulated throughout.
- The designs all use TPB as the exterior wavelength shifter on acrylic plates. The interior wavelength shifting bar is EJ-280. The dichroic filter used is based on a file of transmission percentages vs wavelength spectrum tailored to trap photons for the pTP/TPB wavelength shifter combination.
- For this application the wavelength range has simply been shifted from the pTP emission spectrum to encompass TPB's emission spectrum.



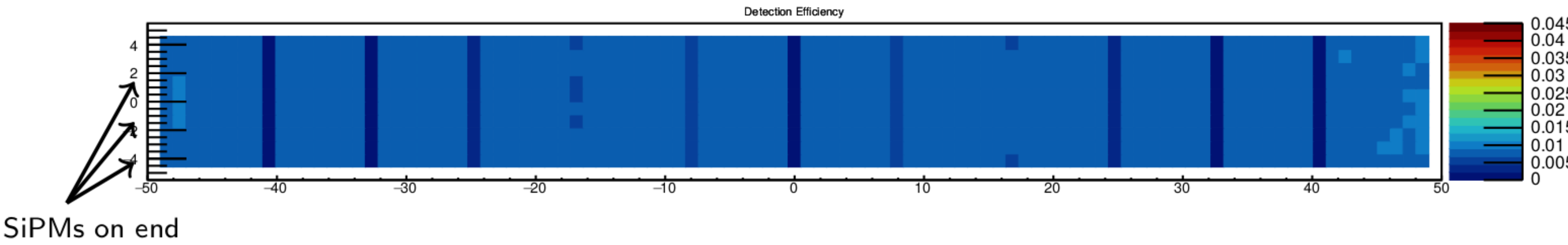
Dichroic filter spectra

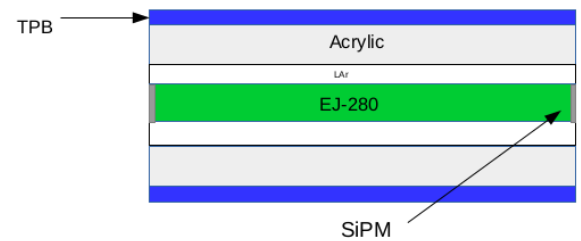




Integral of the tpb emission =57.2
Integral of TPB emission $*$ Transmission% = 39.1
A decrease in transmission of 32%

Double Shift Light Guide - End Detectors





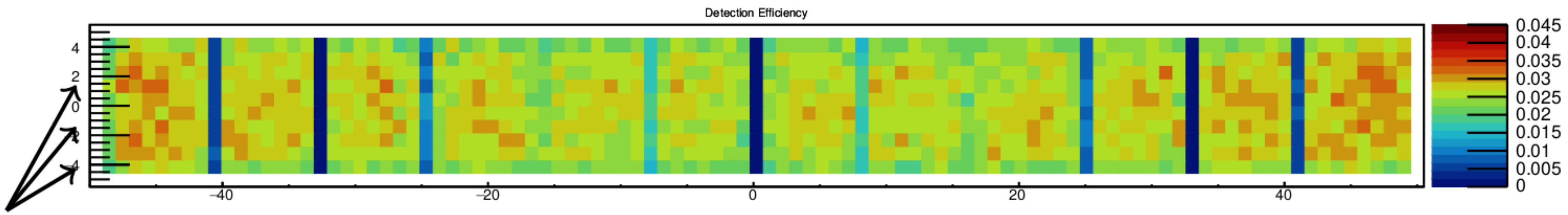
A cartoon for the geometry of this design can be seen to the right.

The resulting effective area is

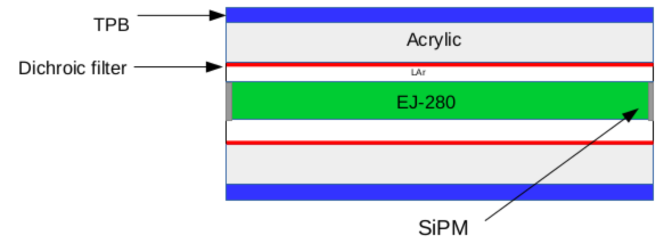
$A_{eff}(2\ Super\ Cells) = 6.67cm^2$

$A_{eff}/SiPM = .28cm^2$

Double Shift Light with Filter Guide - End Detectors



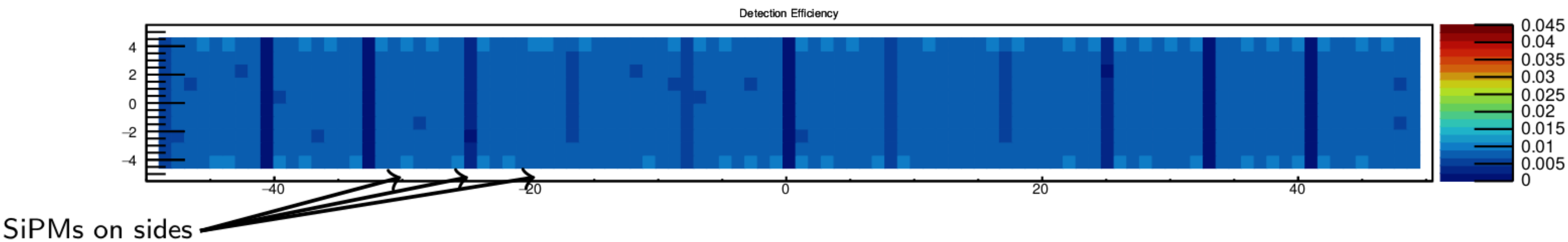
SiPMs on end



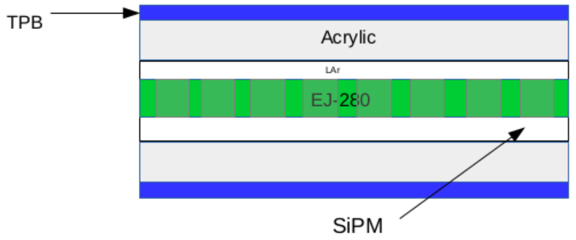
A cartoon for the geometry of this design can be seen to the right.

The resulting effective area is
$A_{eff}(2\ Super\ \ Cells) = 22.11cm^2$
$A_{eff}/SiPM = .92cm^2$

Double Shift Light Guide - Side Detectors

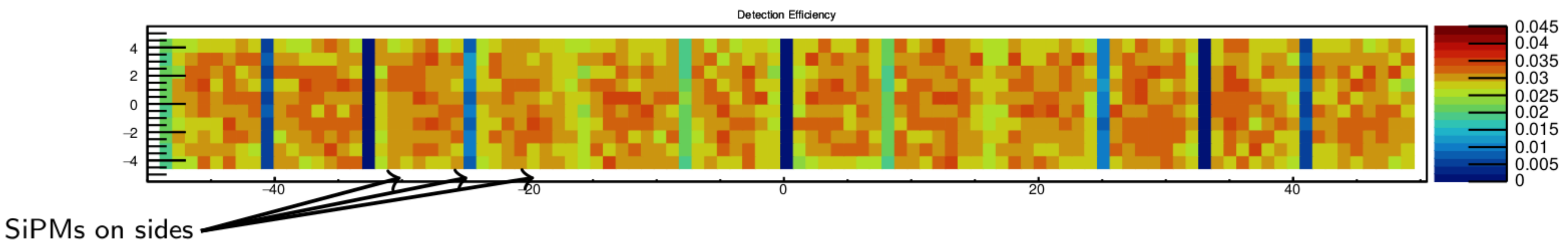


A cartoon for the geometry of this design can be seen to the right.

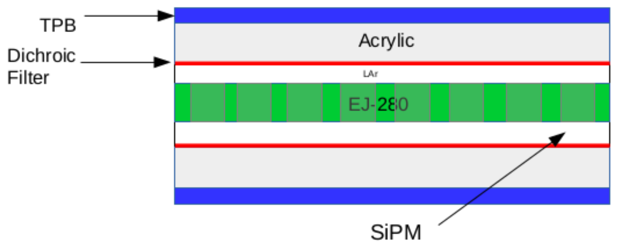


The resulting effective area is
$A_{eff}(2\ Super\ \ Cells) = 6.37cm^2$
$A_{eff}/SiPM = .06cm^2$

Double Shift Light Guide with Filter - Side Detectors



A cartoon for the geometry of this design can be seen to the right.

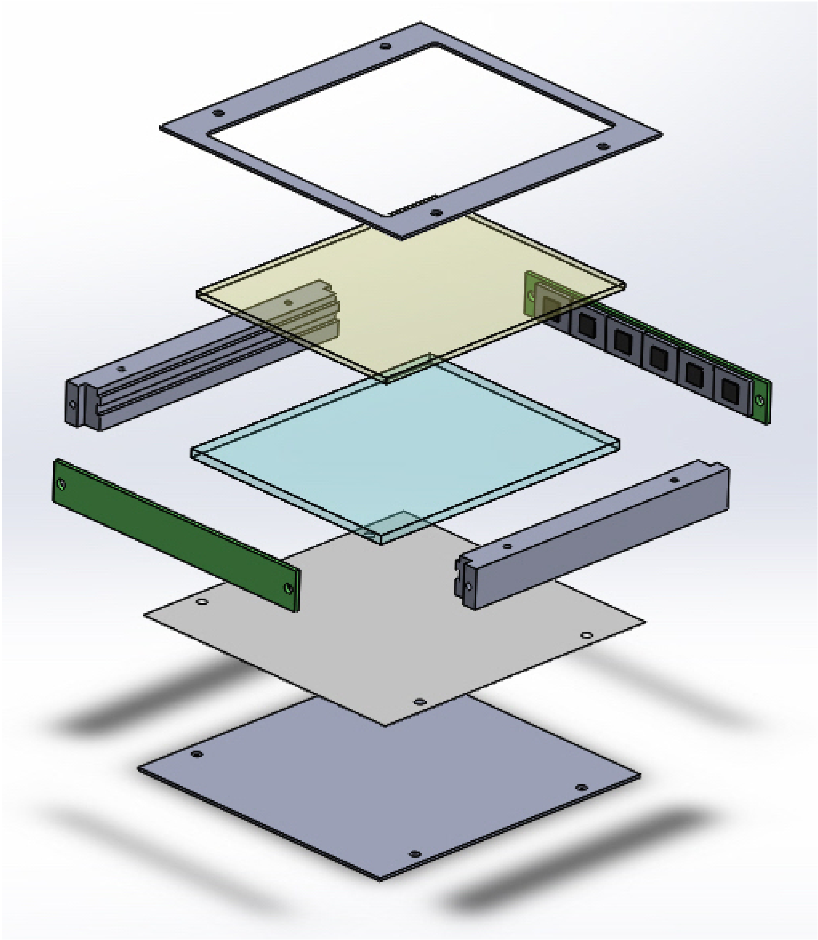


The resulting effective area is

$A_{eff}(2\ Super\ \ Cells) = 25.34cm^2$

$A_{eff}/SiPM = .26cm^2$

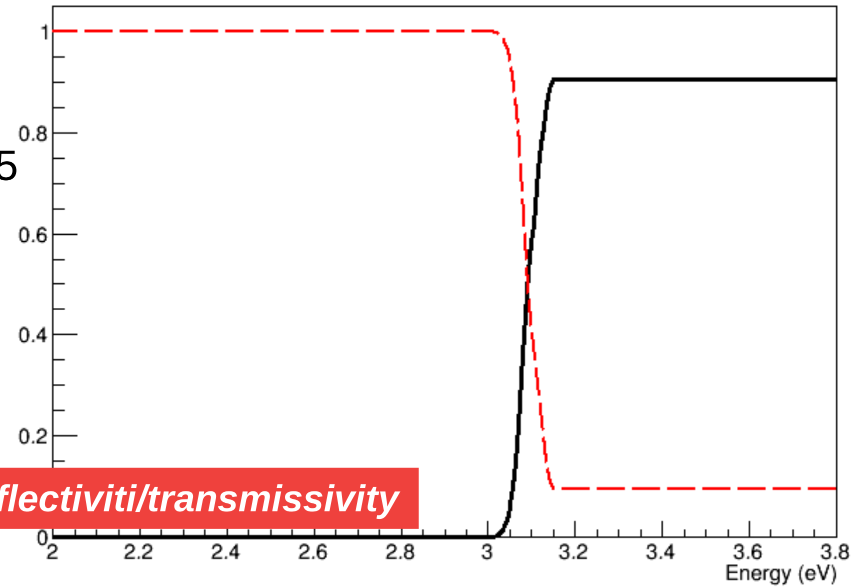
Brazilian simulation



- Simulation of the small X-ARAPUCA cell which is going to be tested in Brazil by the end of this month
- Study limited to trapping efficiency wrt to ARAPUCA. No external shifter simulated, no SiPMs
- 10 cm x 8 cm dichroic filter (no angular dependence at the moment)
- 3 mm thick acrylic plate

Brazilian simulation

- The simulation includes the absorption of the photons inside the acrylic slab, reflections on the internal surfaces, refractive indexes of the materials, reflection/transmission at the boundaries.
- Reflectivity of internal reflector 98%
- Refractive index of acrylic (@430 nm) = 1.5
- Conversion efficiency of WLS plate = 0.9
- Refractive index of Lar (@430 nm) = 1.25
- Absorption length of acrylic = 0.5 m
- No Rayleigh scattering in LA



Filter reflectiviti/transmissivity

- Does not include angular dependencies of the filter and the spectrum of the shifter
- Collection efficiency found to be 53% against of 38% of a standard ARAPUCA with the same SiPM coverage.
- New features developed for the protoDUNE and TallBo ARAPUCAs, will be shortly plugged in: angular dependence of the filter, spectrum of the WLS plate. External shifter
- Supercell simulation under development

Issues raised at protoDUNE review 2-3 August 2016

1. Does the Photon Detector System design enable validation and refinement of the DUNE photon detector requirements ?

Optical system
Answer: Yes, but.

Comments:
The 0.1 pe/MeV requirement seems marginal for DUNE, and hence is a marginal design goal for protoDUNE. Details of the SN burst trigger still need to be worked out. It seems likely that a TPC-based trigger, rather than a PDS trigger, will be developed.

A:Being investigated by DUNE Physics group and by PDS Physics and simulation WG. Requirements in the process of being formulated (see A. Himmel talk)

Recommendation:
Efforts should continue to improve both main light collection schemes and to develop the ARAPUCA scheme. Further R&D should continue in parallel with protoDUNE toward higher-light-yield schemes.
A:Done

Electronics
Answer: Maybe.

Comments:
Small scale tests demonstrate that the SSP digitizer system has low enough intrinsic noise to distinguish single PE signals from three SensL MicroFC-60035-SMT SiPMs ganged together. However, even with the TPC electronics turned off, the noise observed in the 35-ton test was at least 2 times higher than this level. One third of the SiPM channels had anomalous noise significantly higher than this. When the TPC was on and reading out, the noise in the SiPM waveforms was approximately 25 times the level present in small scale tests. ProtoDUNE-SP will operate approximately 3 times more SiPM readout channels than the 35-ton test. There is a significant risk that excessive noise will severely compromise the test of photon detectors in protoDUNE-SP. There is a serious risk that excessive noise in the SiPM readout will prevent the protoDUNE-SP test from providing a validation of the DUNE photon detector requirements or information that would lead to refinements to those requirements.

A:No excessive noise in protoDUNE. In any case the interference issue of PD with other subsystems (which will not be exactly the same of protoDUNE) will be invetigated in dedicated test at Fermilab (ICEBERG set-up) and in the protoDUNE SP Cold Box.

2. Are Photon Detector System risks captured and is there a plan for managing and mitigating these risks?

Optical system
Answer: Not completely.

Two risks are identified: FD-073 – Photon light yield too low; FD-098 – ProtoDUNE-SP Degraded Photon Detectors.
Estimates that predict meeting the 0.1 pe/MeV requirement are based on an estimate that 0.5% of the primary UV ends up wave-shifted and captured in the lightguide bars (Himmel, Slide 14). Actual measurements of this quantity with recent prototypes give ~0.1% (Whittington, Slides 14, 16), with recently-achieved improvements of about factor of 2 (Mufson, Slide 13).

MicroBooNE saw huge rates of single pe's.

Comments:
The Committee thanks the presenters for walking us through the capture efficiency issue.
While the light-yield risk is identified, neither current default scheme appears likely to meet the requirement.
The QA/QC plan presented to us should successfully mitigate the risk of degraded PD modules.
MicroBooNE is a different experiment, but efforts to understand the high photon rate and understand its origin are needed to know if the protoDUNE-SP's PDS will be crippled by the same effect.
A:X-ARAPUCA designs ensures a much higher efficiency which meets the current requirements (higher thatn those considered for the protoDUNE review)
MicroBooNE effect will be investigated in protoDUNE

Mechanical
Answer: Not completely.

Does not apply. Related to CERN operation.

Electronics
Answer: No.
Findings:
See Item 1.
Comments:
See Item 1. Chasing down noise issues can be very time-consuming. Even fixable noise problems could derail the already-tight schedule with respect to beam before the CERN Long Shutdown.
Recommendation:
Add to the risk registry the risk that the protoDUNE-SP photodetector system will not provide information of sufficient quality to inform the DUNE design because excess noise degrades the quality of waveform digitization. Pursue mitigation of this risk with an

Recommendation:
Add to the risk registry the risk that the protoDUNE-SP photodetector system will not provide information of sufficient quality to inform the DUNE design because excess noise degrades the quality of waveform digitization. Pursue mitigation of this risk with an aggressive attempt to understand the sources of noise in the 35-ton test (as is being done for the APA readout).
Add to the risk registry schedule risk from having to hunt down and fix noise. Mitigation strategies include prototype testing (described under Item 9) and early operation of electronics on assembled APAs, which could be interleaved with installation tasks.

A:Agreed, see previous answer.

3. Does the design lead to a reasonable production schedule, including QA, transport, installation and commissioning?

A:Does not apply.

4. Does the documentation of the Photon Detector System technical design provide sufficiently comprehensive analysis and justification for the Photon Detector System design adopted?

Answer: Not addressed by committee.
Comment:
The committee was not presented with discussion of alternate designs, except for the three to be implemented in protoDUNE-SP. At this point, it didn't seem useful to dig into this, as the designs presented to us will be implemented. However, as we have reservations about the light yield (both the requirement and that achieved so far) and have recommended (see Charge items 1 and 2) that variants be explored in parallel with protoDUNE, we present a recommendation anyway.
Recommendation:
Though we were shown (Himmel, slides 15-16) projected efficiencies vs. distance from anode plane for various thresholds (in pe), the impact of these efficiencies on the physics that can be extracted, especially from SN bursts, has not been studied in detail. A study should be performed documenting the impact of PDS light yield on SN physics, specifically at values of 0.1, 0.05, 0.02 pe/MeV at the CPA.A

A:Very important comment from the committee. SN requirement development is being studied in very details by the Physics Group. Translation of the physics requirements into detector requirements is one of the main commitments of the Consortium. X-ARAPUCA design seem to give enough guarantees that requirements can be met (even if not yet completely defined yet) given also the possibility of tuning the Detection Efficiency by increasing/ decreasing the number of SiPM

5. Is the Photon Detector system scope well defined and complete?
Answer: Yes, in all areas.

6. Are the Photon Detector System 3D model(s), top level assembly drawings, detail/part drawings and material and process specifications sufficiently complete to demonstrate that the design can be constructed and installed?
Answer: Yes.

7. Are operation conditions listed, understood and comprehensive?

Comment:
The Committee never understood this part of the charge.

Is there an adequate calibration plan?
Answer: Partly.

Finding:
A UV-LED/optical fiber/diffuser system will have diffusers mounted on the CPAs.

Comment:
The design of the UV-LED system is nearing completion and was presented in detail to us. The LED system is more a monitoring system (devices working and stable) than a calibration system.
Recommendation:
A calibration plan, including, for example, channel-to-channel timing offsets, t0 timing for the TPC, light yield and resolution vs. 3D position, should be developed.

A:Agreed, Consortium is working on a detailed calibration plan for the PDS system. We will have led flasher also in DUNE. Calibration using ^{39}Ar will be tested in ICEBERG.

8. Are the Photon Detector System engineering analyses sufficiently comprehensive for safe handling, installation and operation at the CERN Neutrino Platform?

A:Does not apply.

9. Have applicable lessons-learned from previous LArTPC devices been documented and implemented into the QA plan?

Recommendation:
As part of the effort to avoid excess noise in the SiPM readout, we recommend tests of the readout of (even a partial) APA assembly including both TPC electronics and photon detectors. Either or both of the FNAL and BNL test systems could be modified to includeSiPM readout.

A:These tests will be done with the ICEBER set-up and possibly at CERN in the protoDUNE SP Cold Box.

Summary

- SP PD Consortium accounts from **40 Institutions** equally distributed in *Latin America*, *North America* and *Europe*
- Baseline design based on the **X-ARAPUCA concept**
- Two **well motivated SiPM candidates** are under evaluation and extensive tests are being carried *inside the Consortium*
- Two different flavors of ***active ganging electronics*** have been successfully developed
- *Low cost read-out electronics in a well advanced stage*
- **Two options** to improve the performances of the PDS are *under study*