Detection efficiency of the X-ARAPUCA

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on behalf of the Lab. Leptons Group

XXXV ANNUAL MEETING DPYC-SMF

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Outline

I. Cryogenic Liquid-Argon Detectors

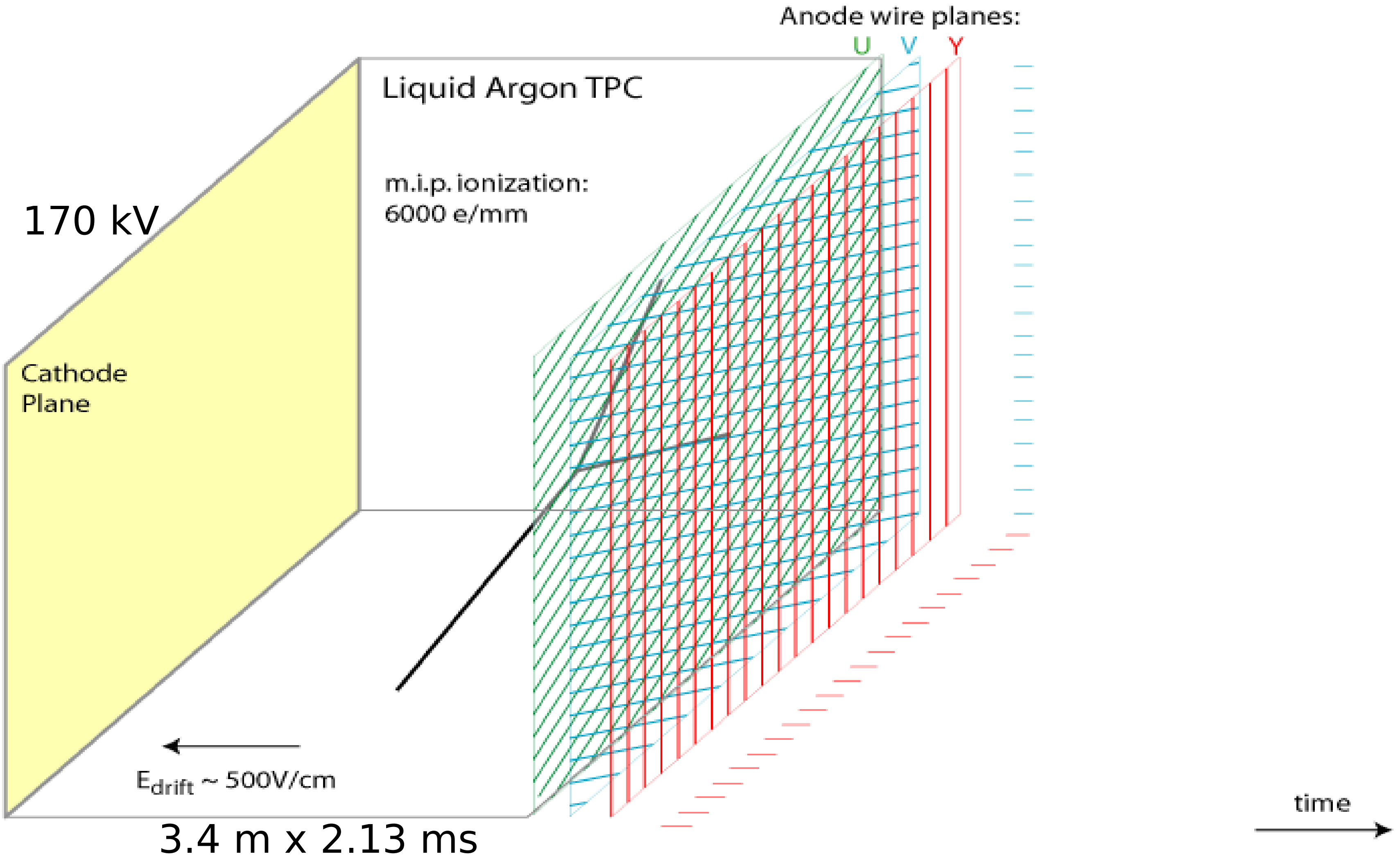
II. Photo-detection system

III. ARAPUCA

- III. 1. LAr test of X-ARAPUCA

IV. Conclusions

Time projection chamber (single phase)



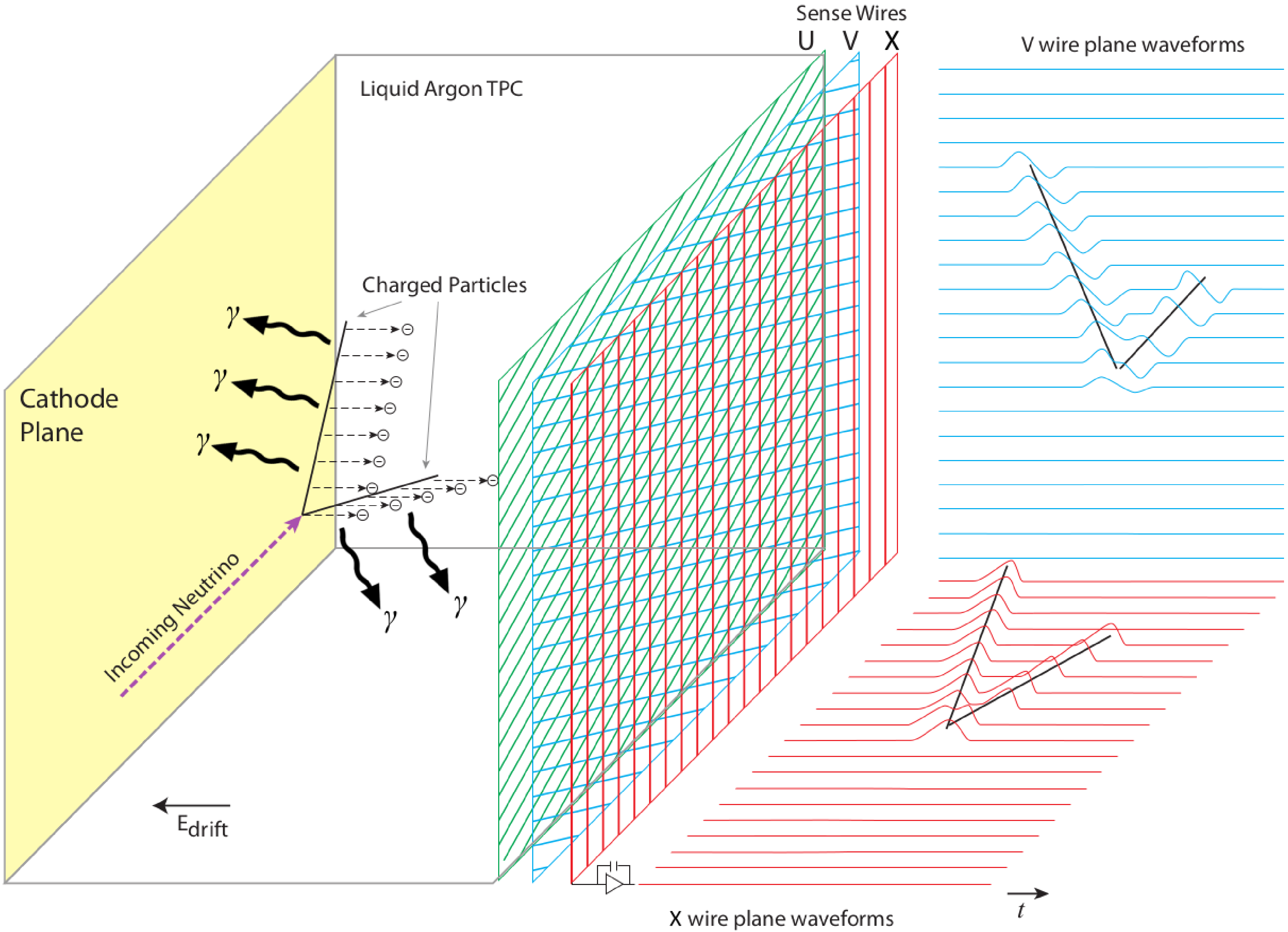
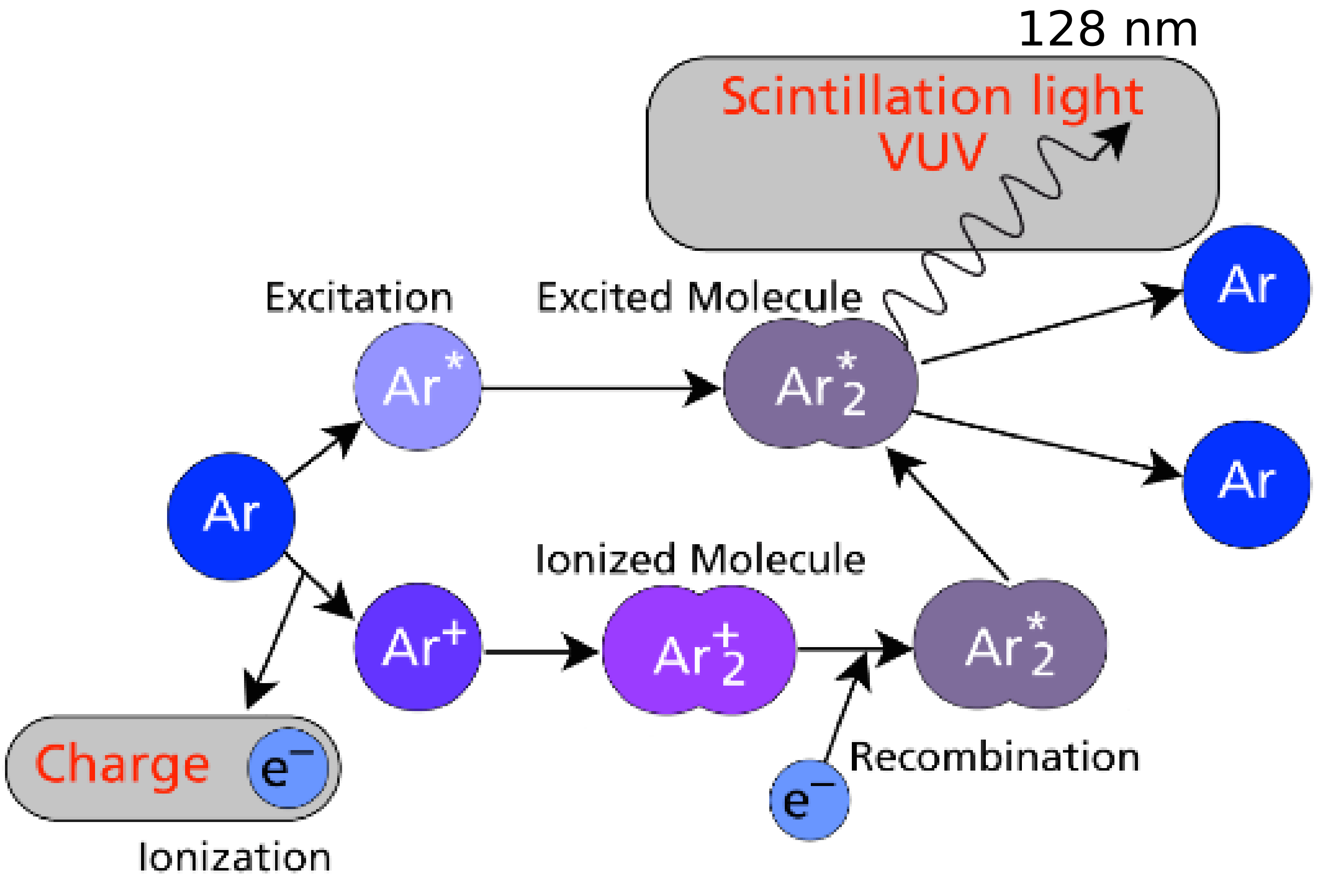
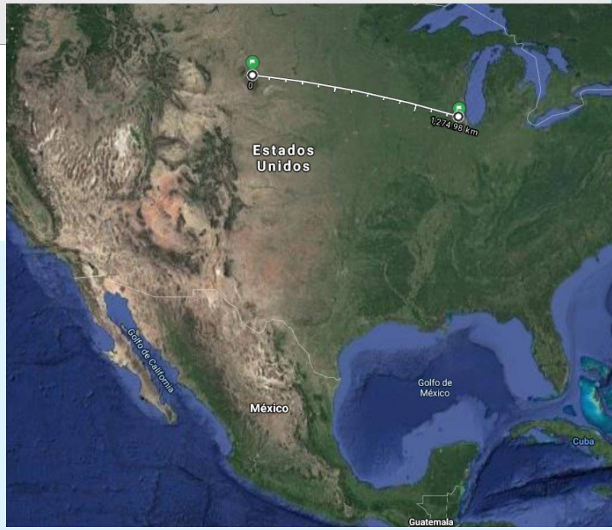

Sense Wires
U V X
V wire plane waveforms
Liquid Argon TPC
Charged Particles
Cathode
Plane
γ
γ
γ
γ
γ
Incoming Neutrino
Edrift
X wire plane waveforms
t

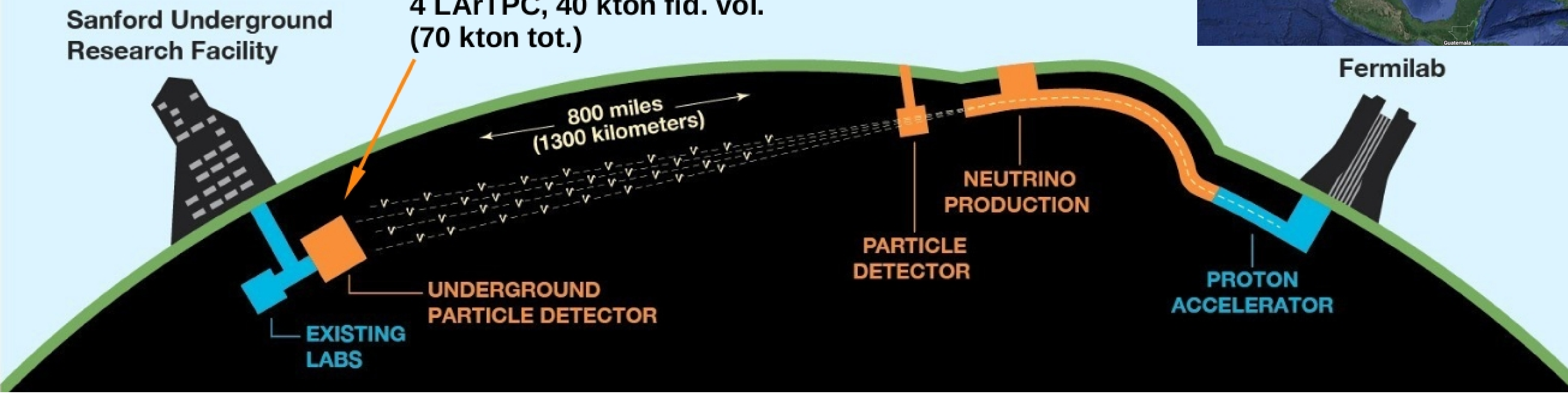
Photo detection



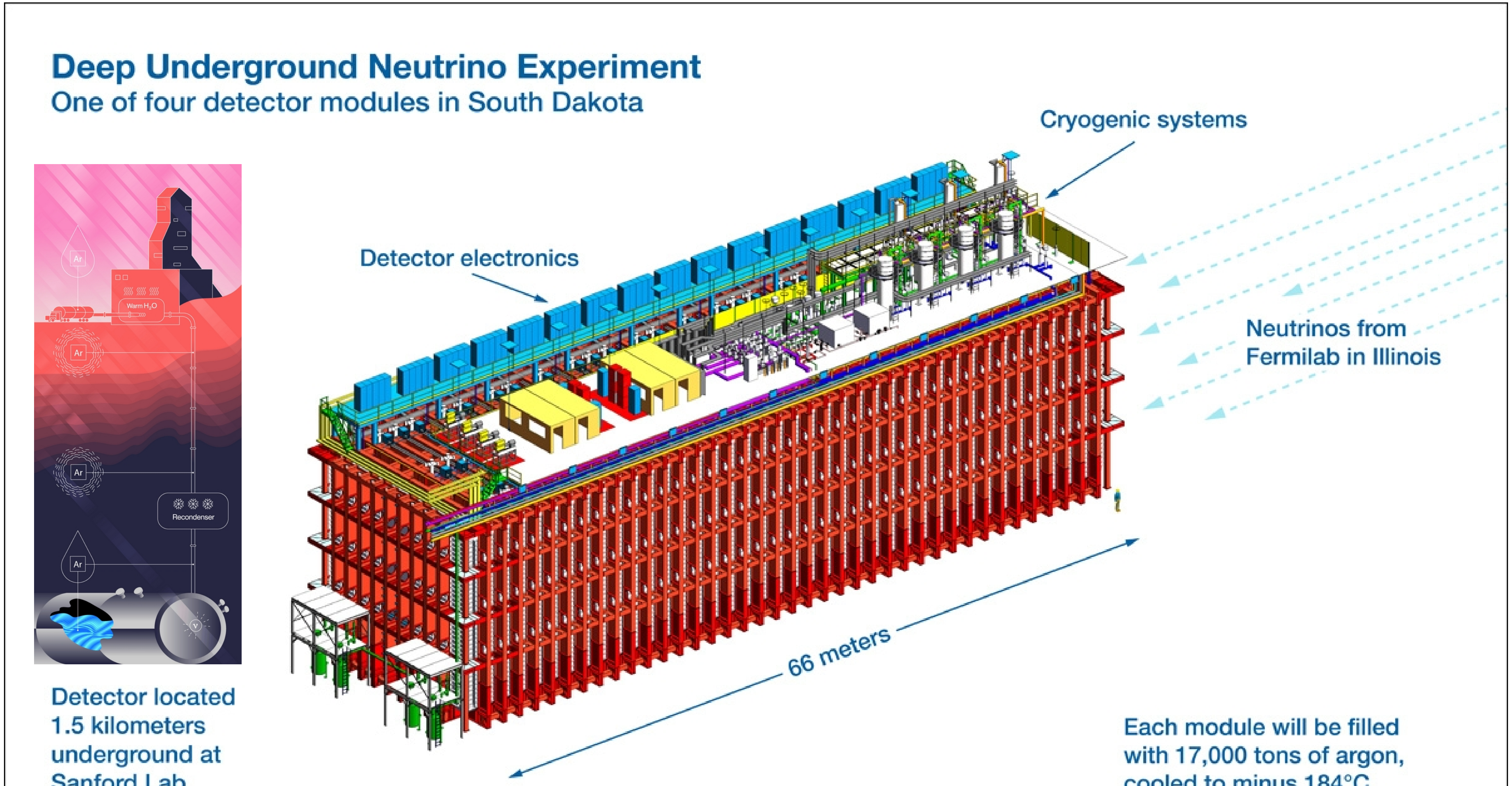
- Fast (7 ns) and slower (≈1500 ns) components, corresponding to single and triplet states of excited molecule
- Argon scintillation light is very abundant (40 k photons/MeV)
- Need wavelength shifter (TPB, PEN) to shift VUV to visible
- Several technology options under consideration (PMTs, SiPMs….)
- Provides timing and event reconstruction
- Complementary to charge readout

Deep Underground Neutrino Experiment (DUNE)



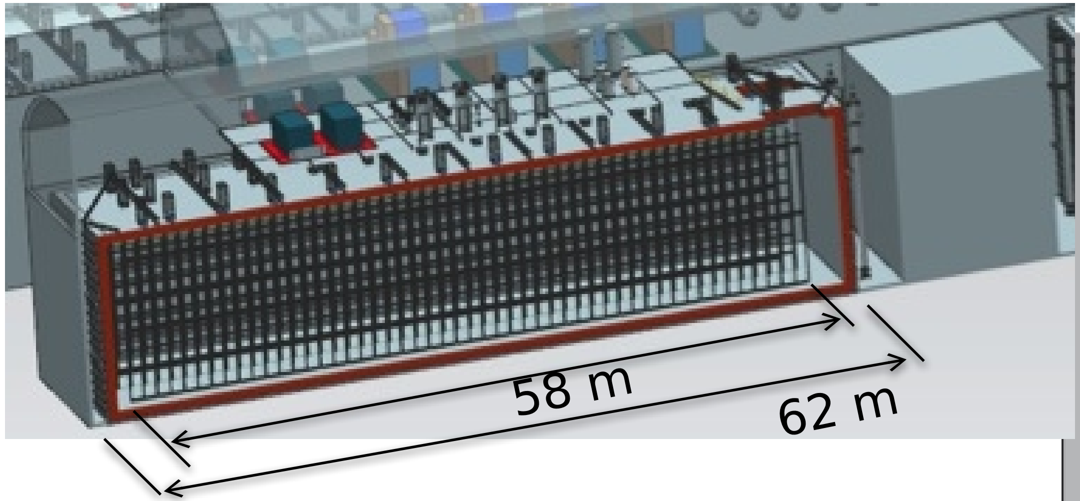


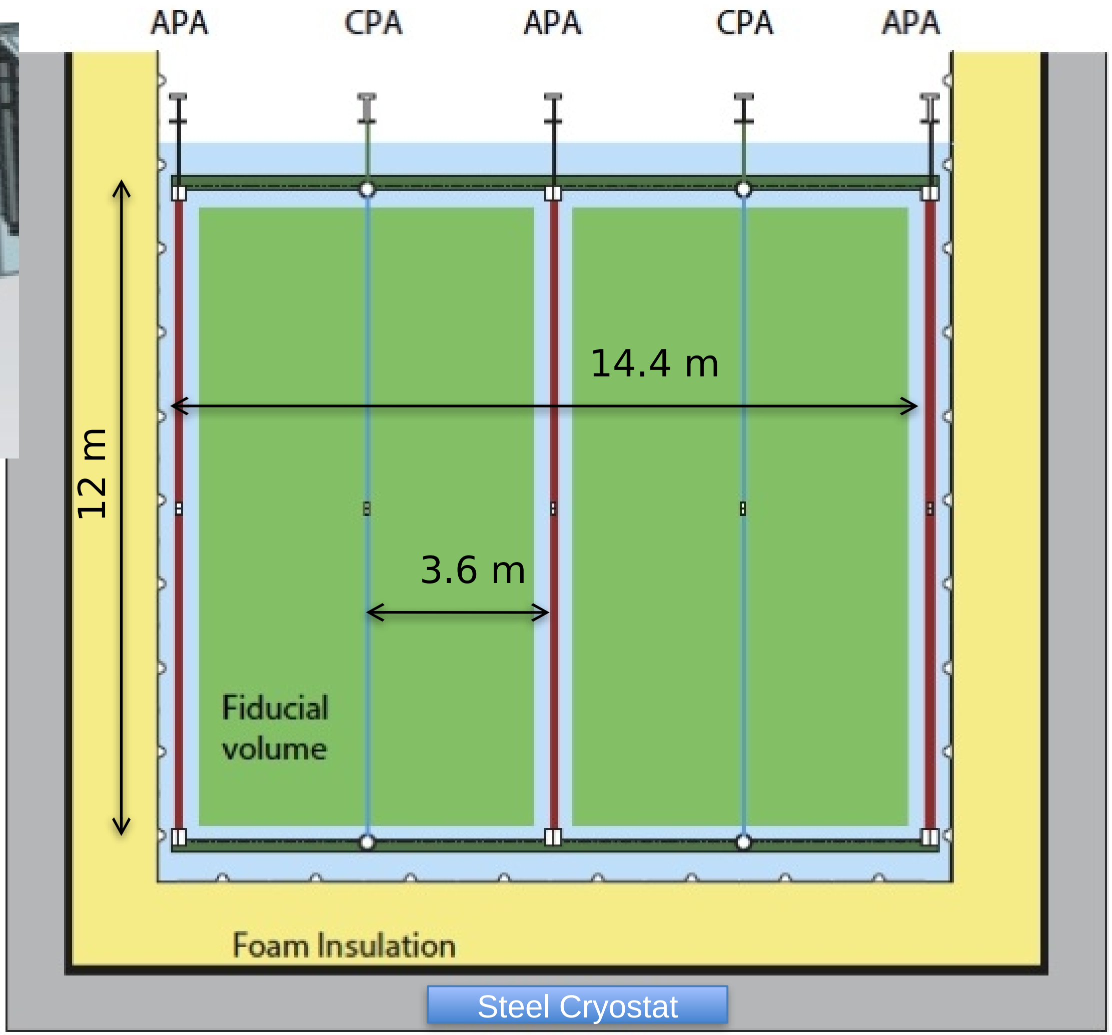
Free-standing steel cryostat



1000 trucks with 20 ton of LAr

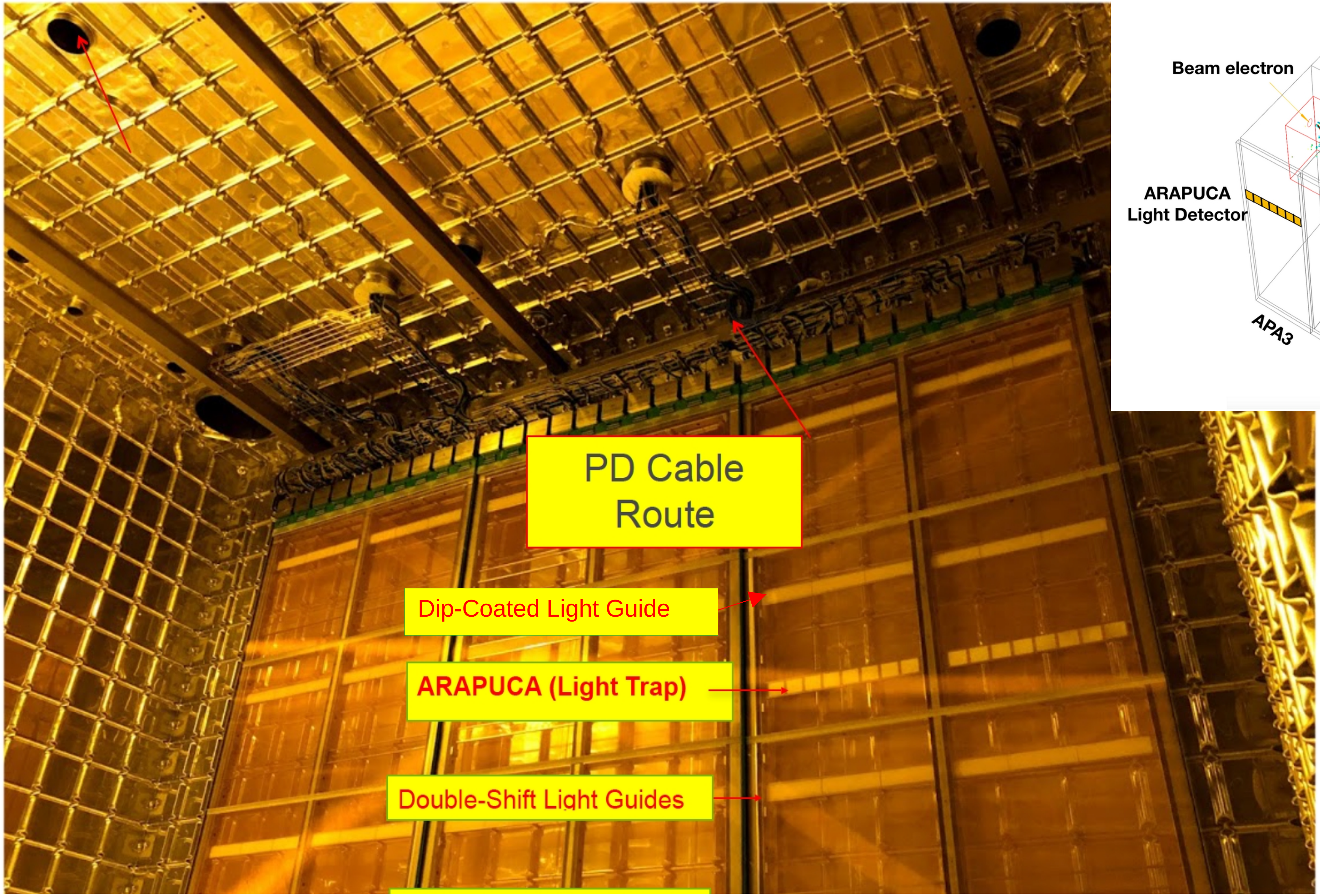
Two single-phase detectors

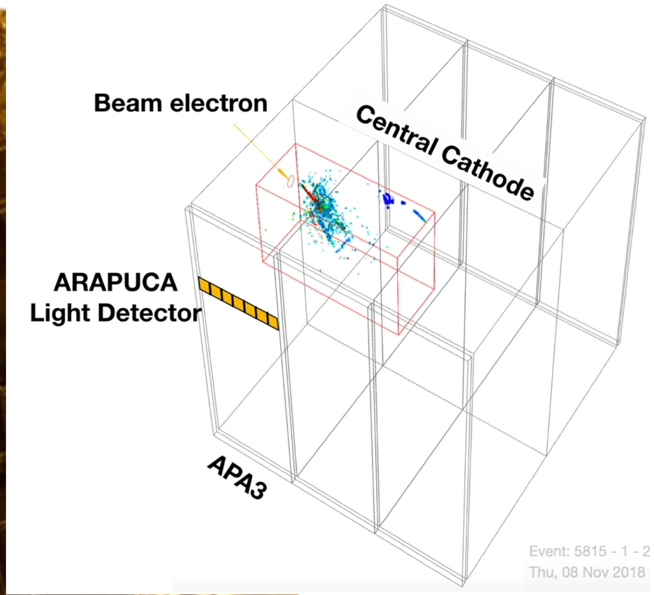




- 150 Anode Plane Assemblies (APA) per detector
  - Cold electronics 384,000 channels
- Cathode planes (CPA) at 180 kV
  - 3.6 m max drift length

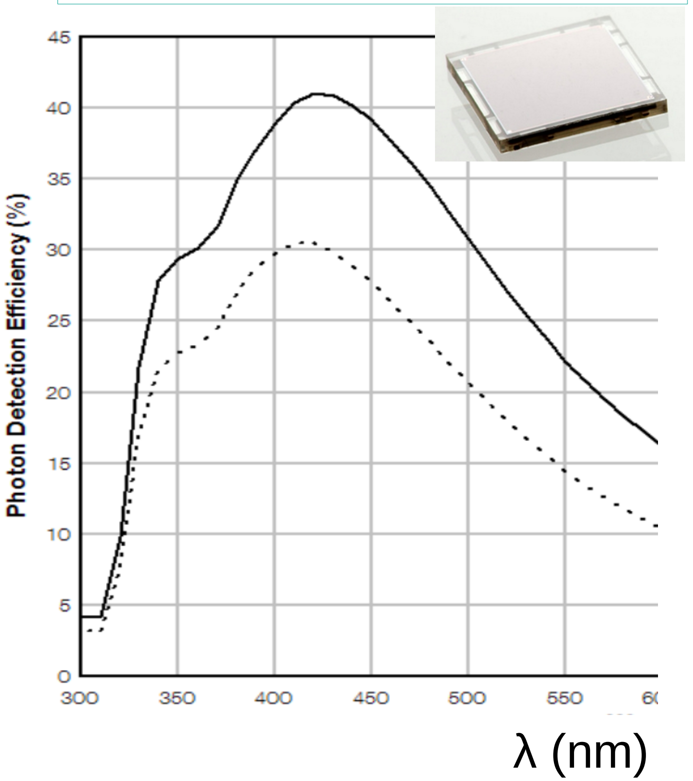
Photo-detection system

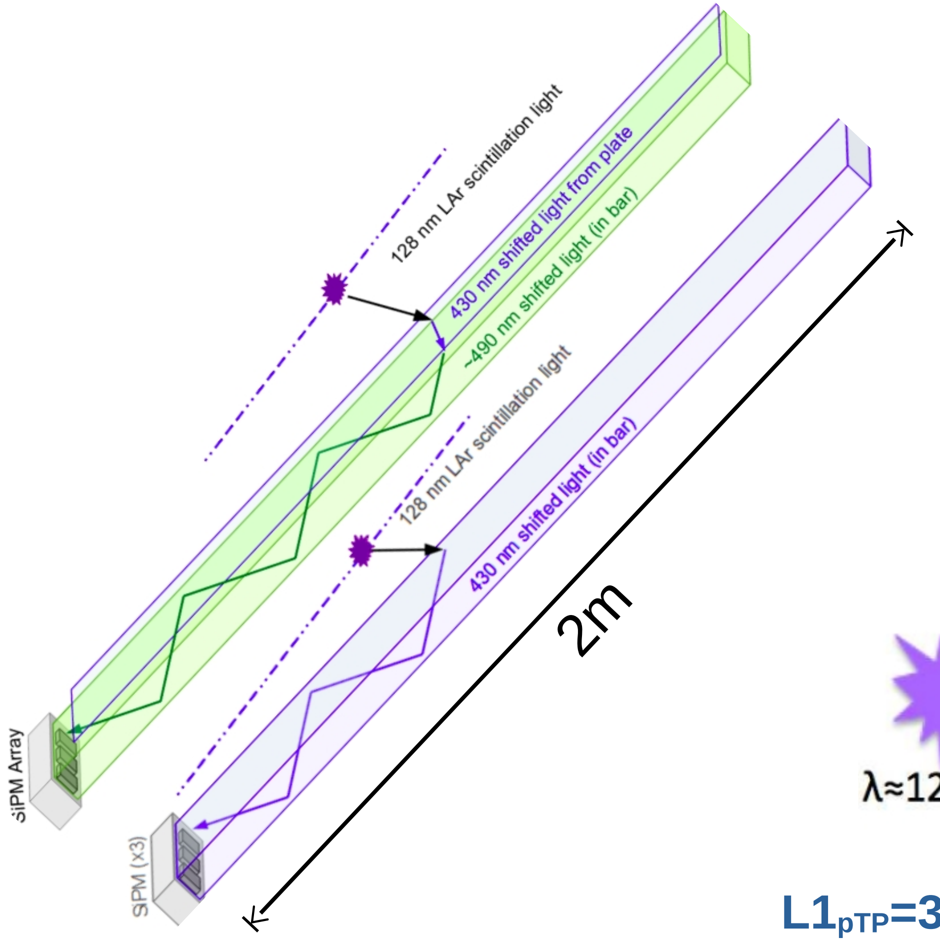

PD Cable
Route
Dip-Coated Light Guide
ARAPUCA (Light Trap)
Double-Shift Light Guides


Beam electron
Central Cathode
ARAPUCA
Light Detector
APA3
Event: 5815 - 1 - 2
Thu, 08 Nov 2018

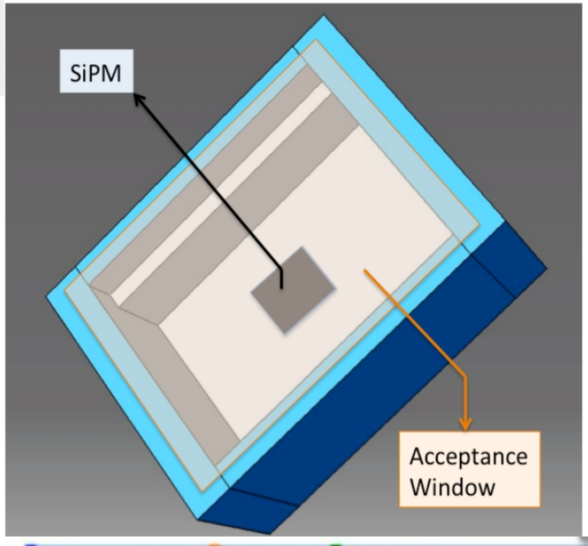
ProtoDUNE Photo-detection system

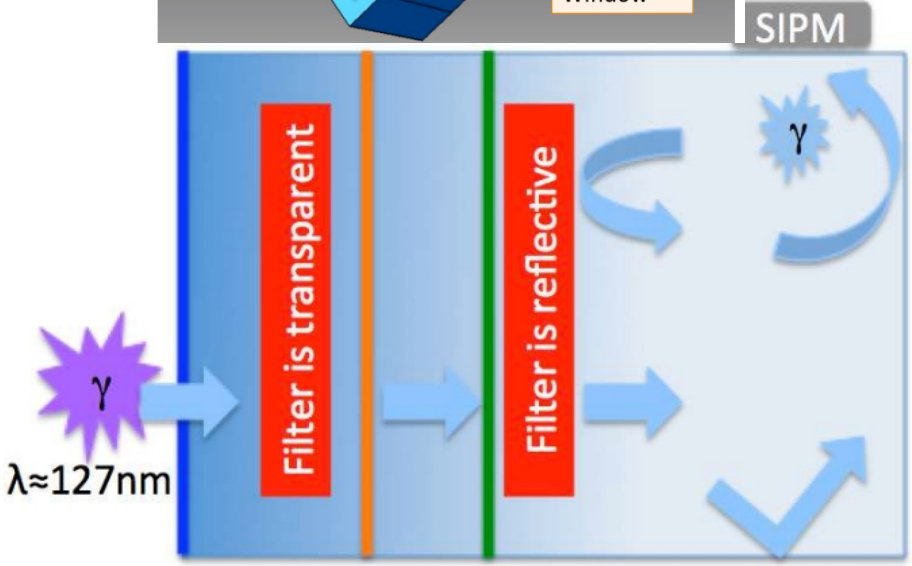
SiPM: SensL 60035
6×6 mm²
Efficiency (5V, 420nm):
41%





3.5 × 2.3 cm²



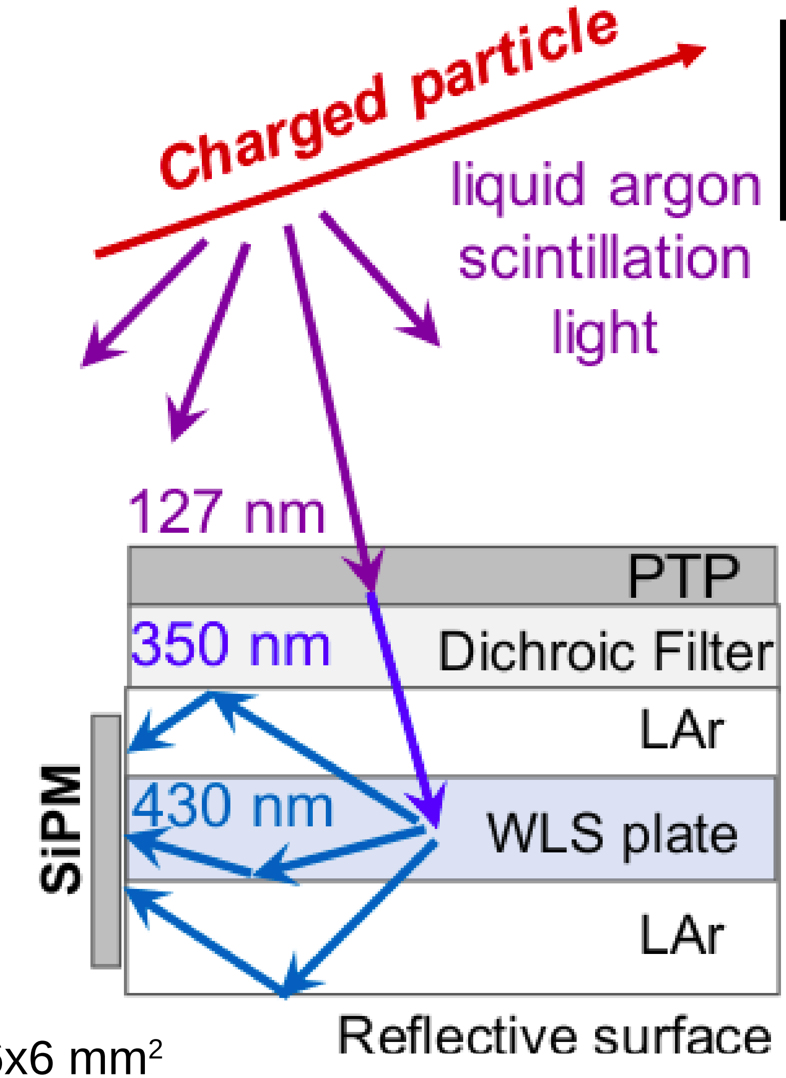


$L1_{pTP}$=350 nm, Cut=400 nm, $L2_{PTB}$=430 nm

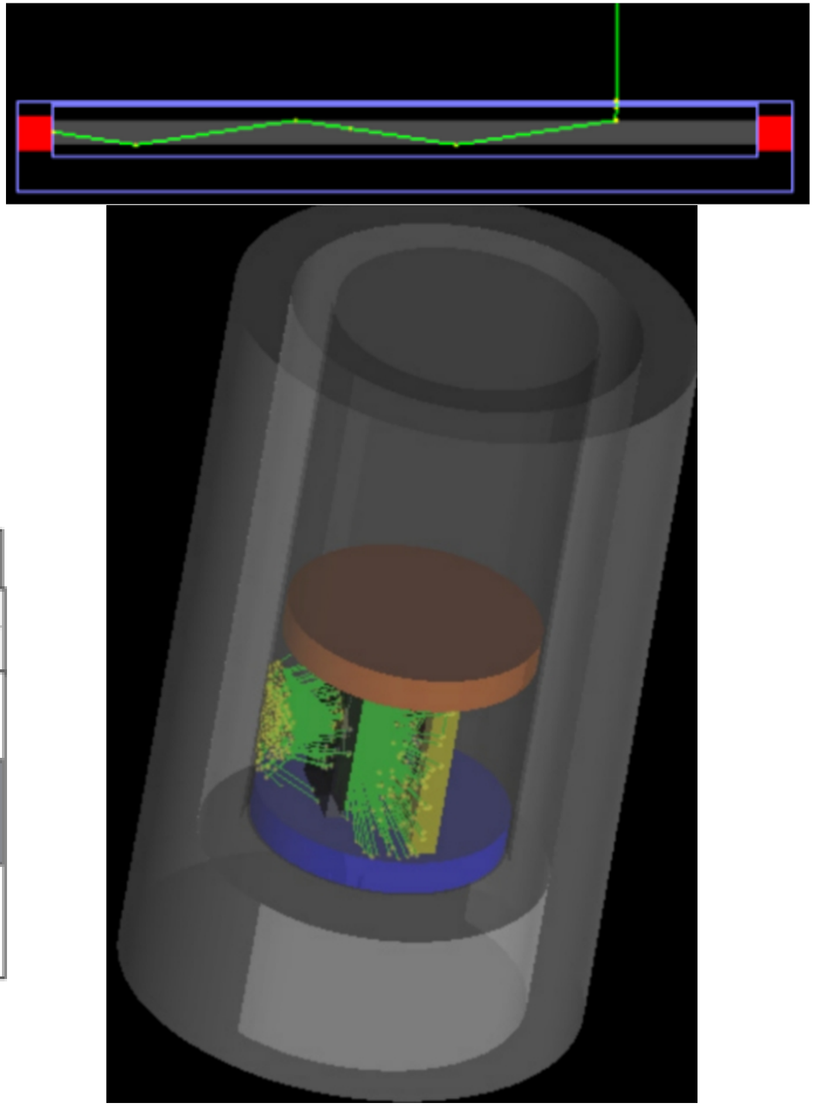
The DUNE collaboration, FERMILAB-CONF-16-604-ND-PPD (2016)

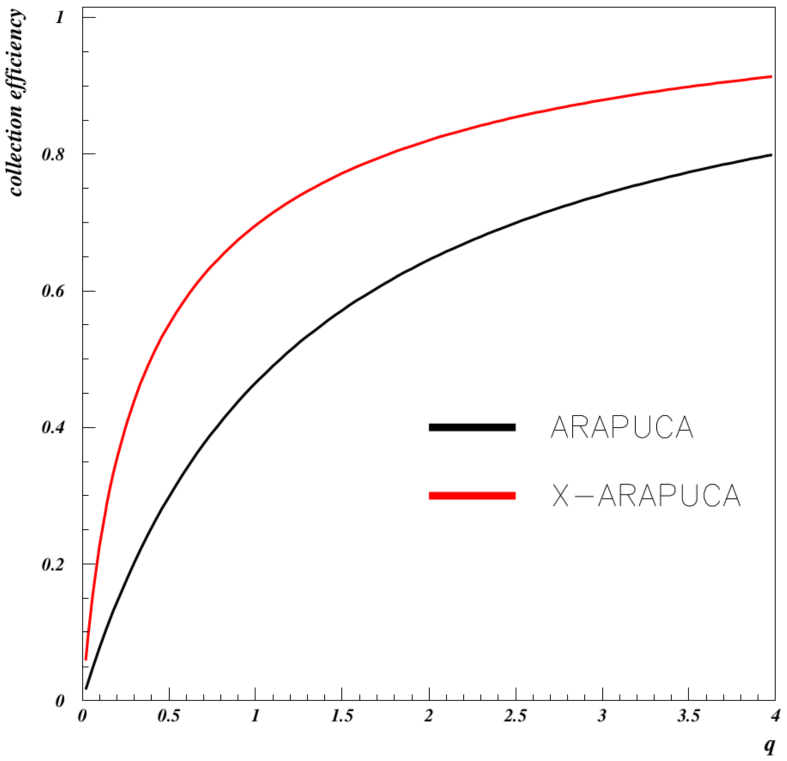
A.A. Machado, JINST 11 C02004 (2016)

X-ARAPUCA(X-A) - The improvement of ARAPUCA (S-A)



6x6 mm²
Hamamatsu S13360-6050VE



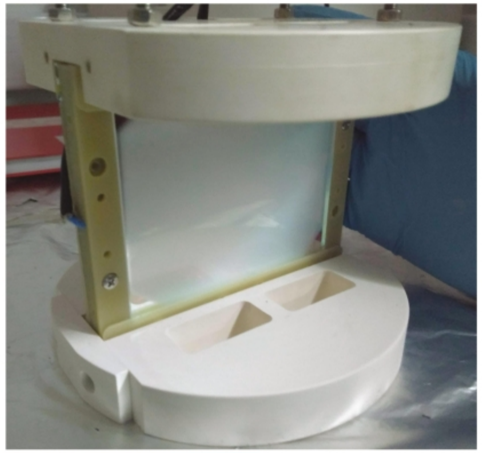


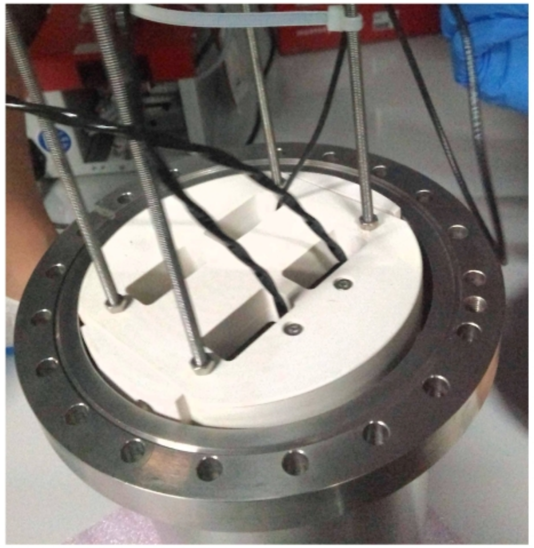
S-A= 2.2% ± 0.5%
→
X-A= 4.2%± 0.9%

A.A. Machado, JINST 13 C04026 (2018)

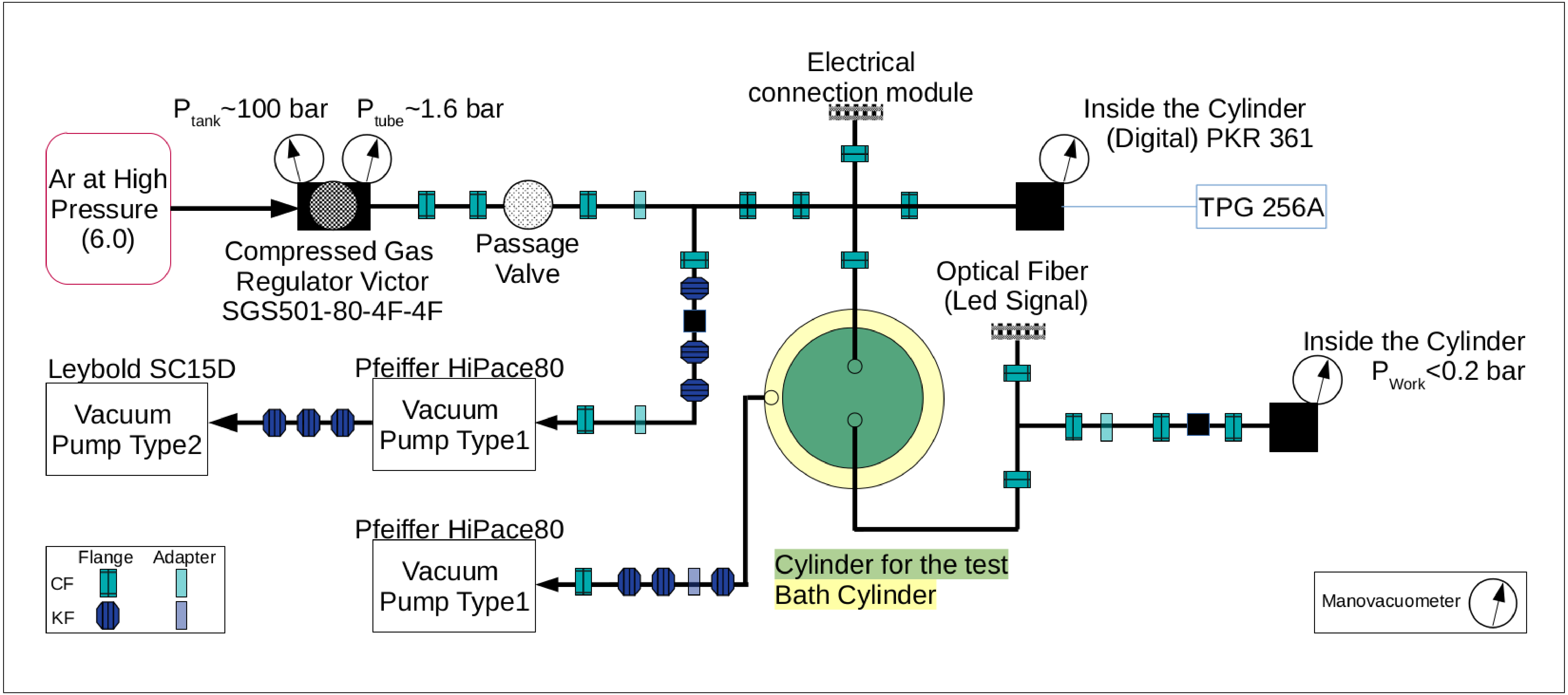
LAr test of X-ARAPUCA

Test of X-ARAPUCA single and double sided



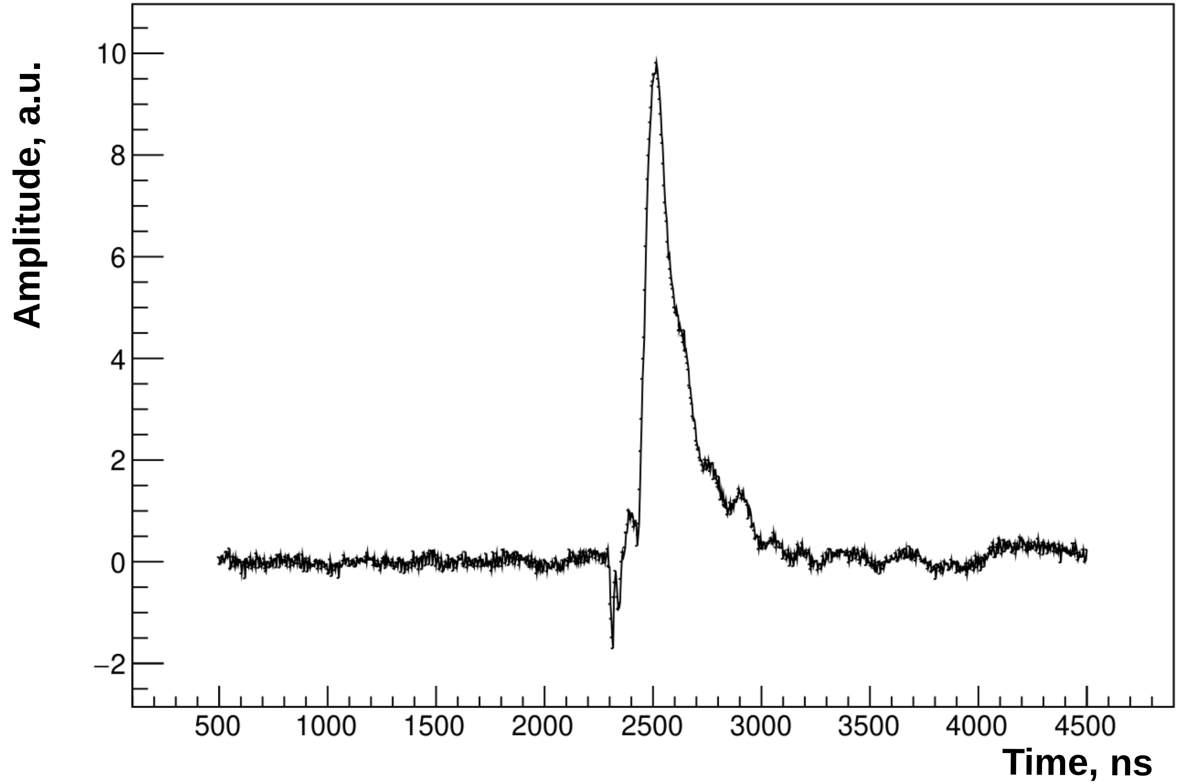


Vacuum flux diagram

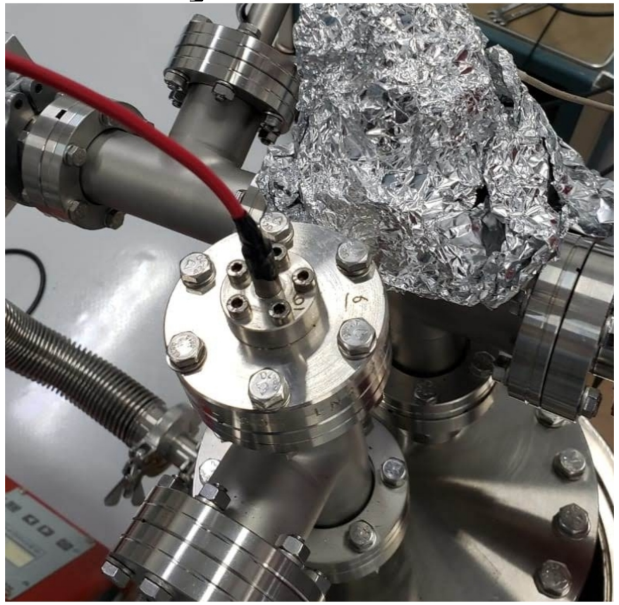


Calibration

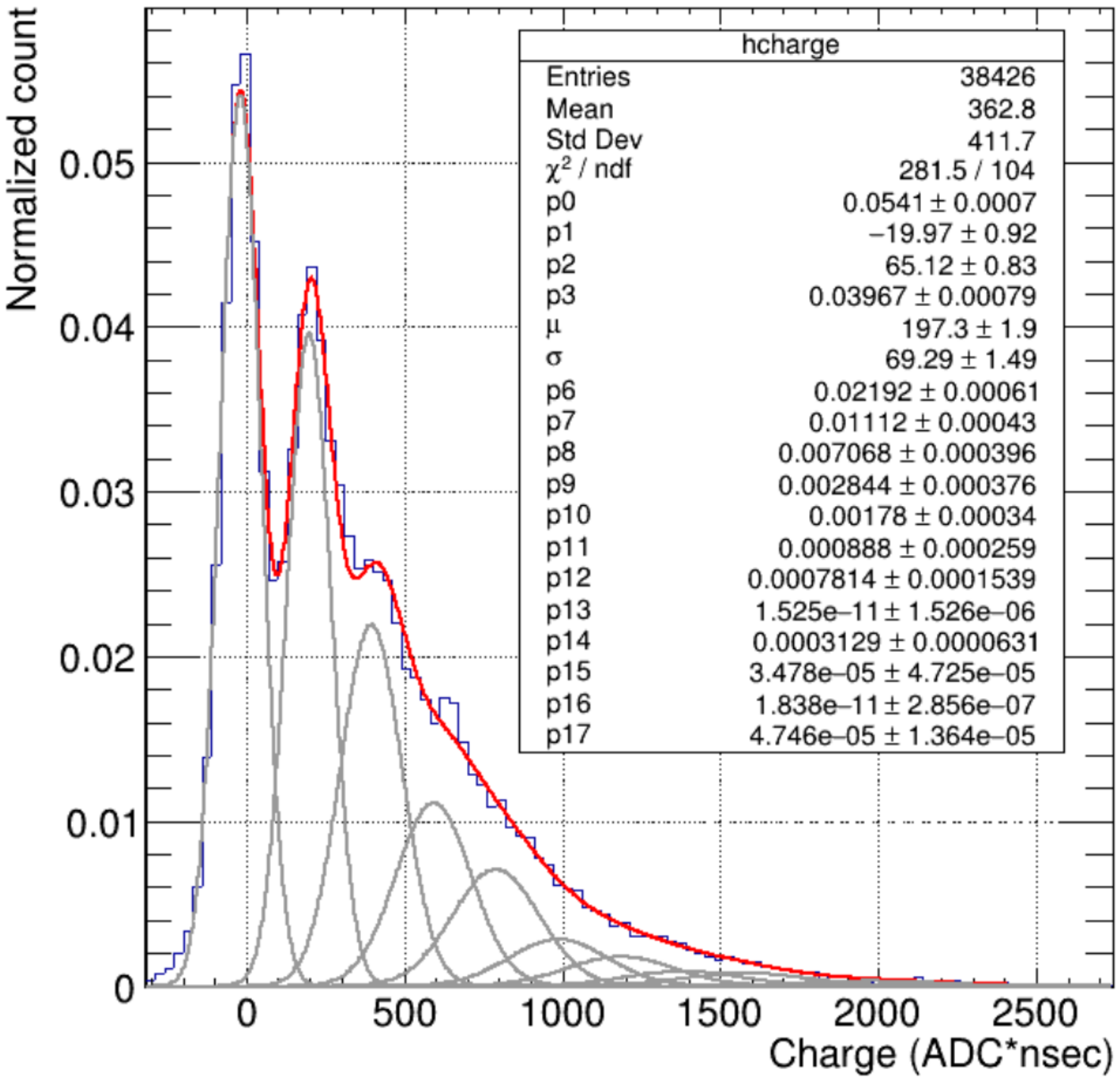
A vacuum tight optical feed-through was installed in the system which brought the flashes of a pulsed LED inside the stainless-steel cylinder.



- LED configuration was chosen to maximize the number of photo- electrons first peak.
- Vcc = 3V, Width = 100 ns, Frequency = 1 kHz
- Pre amplification of 10 times was necessary to calibrate.



Calibration: Cross-talk



- We assume a Poisson distribution:

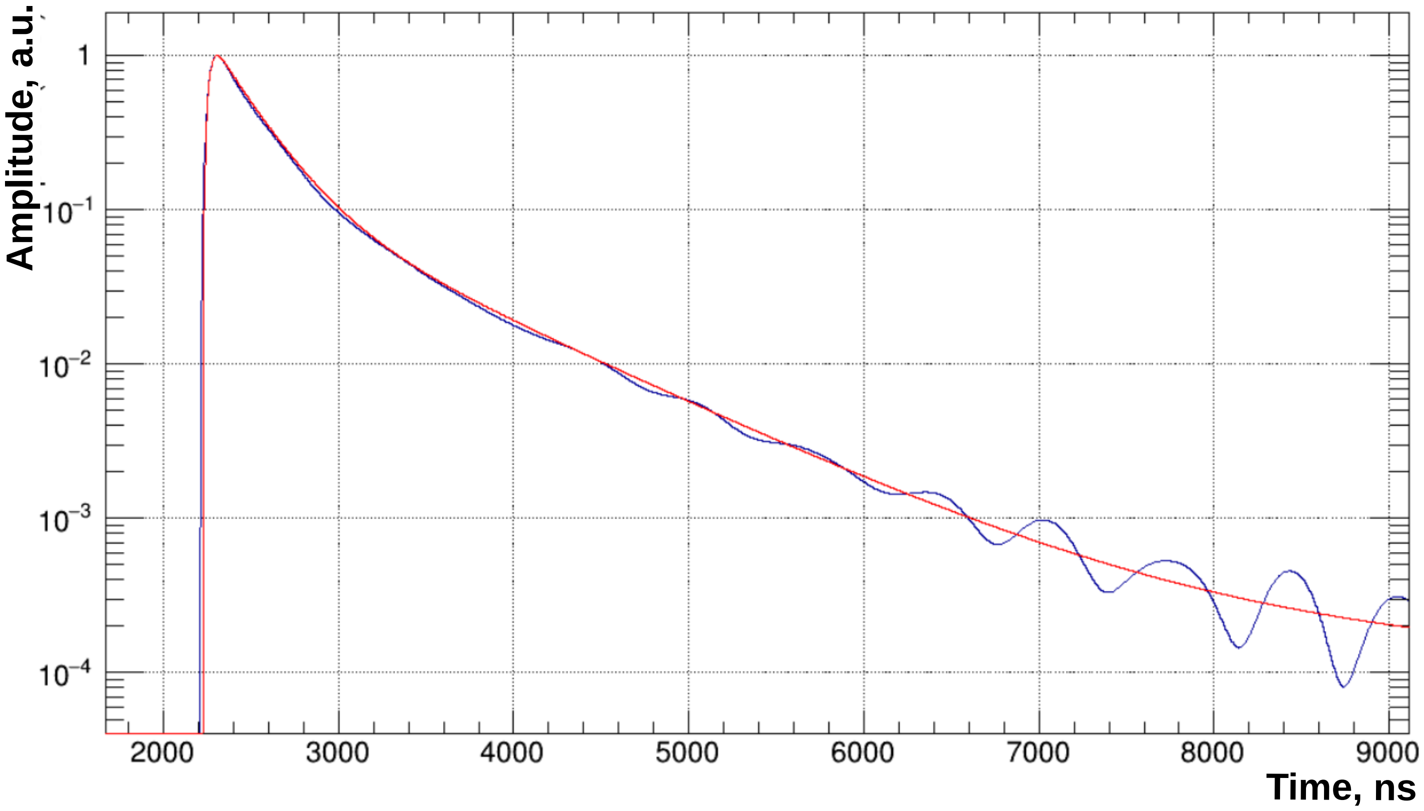
$$P(k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

- Cross talk factor:

$$SPhe'_{charge} = SPhe_{charge} \times CT$$

$\mathrm{CT} = 2.6$ avalanches/photons at 47.5 V

LAr purity - Mean signal analysis



A slow time component of 0.8μs was found.

For alpha particles τ_s = 1.81μs in ultra pure LAr purity factor =44% . Reasonable LAr purity

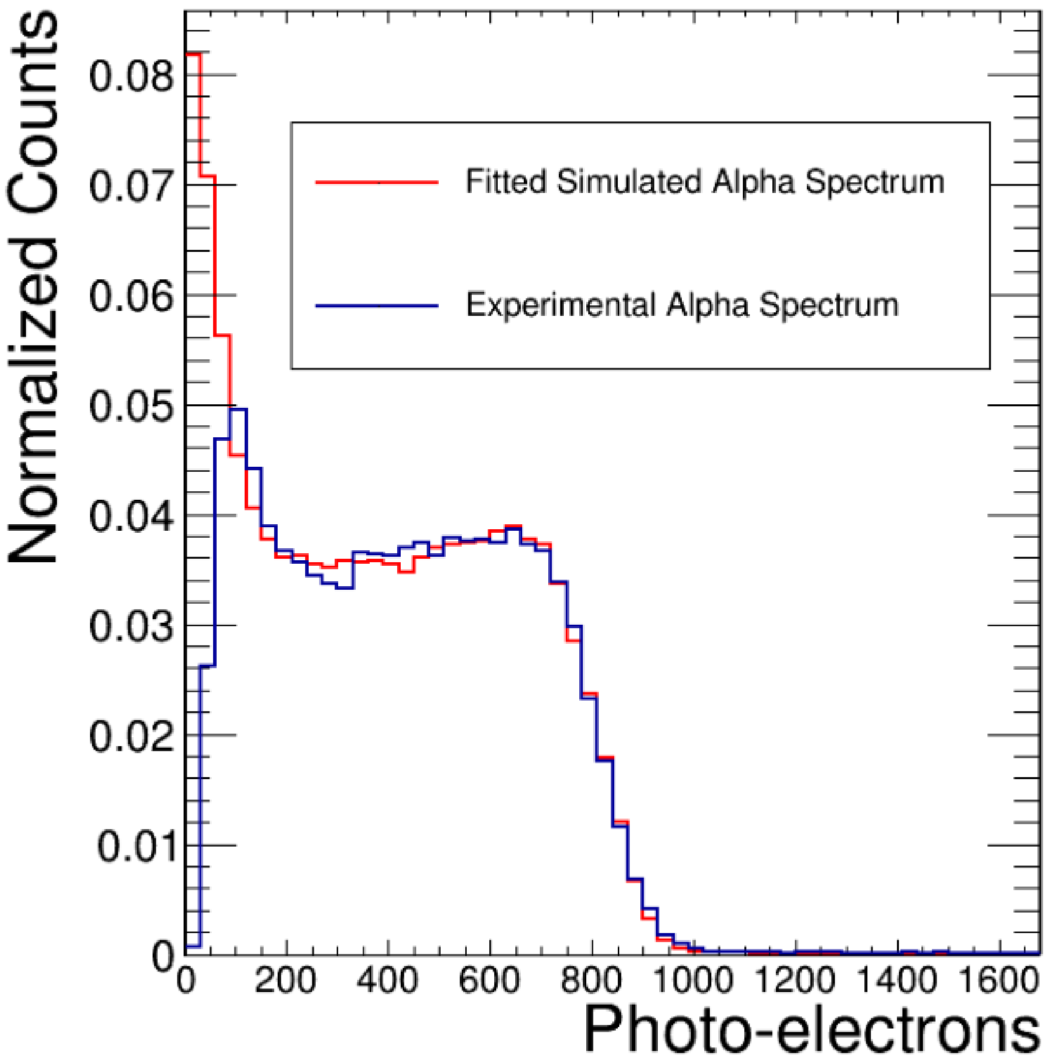
Correction factor = 1.15

$$L(t) = \frac{A_f}{\tau_f} e^{-t/\tau_f} + \frac{A_s}{\tau_s} e^{-t/\tau_s} + \eta_s \frac{N}{[1 + Aln(1 + t/t_a)]^2 (1 + t/t_a)}$$

with Gaussian Convolution

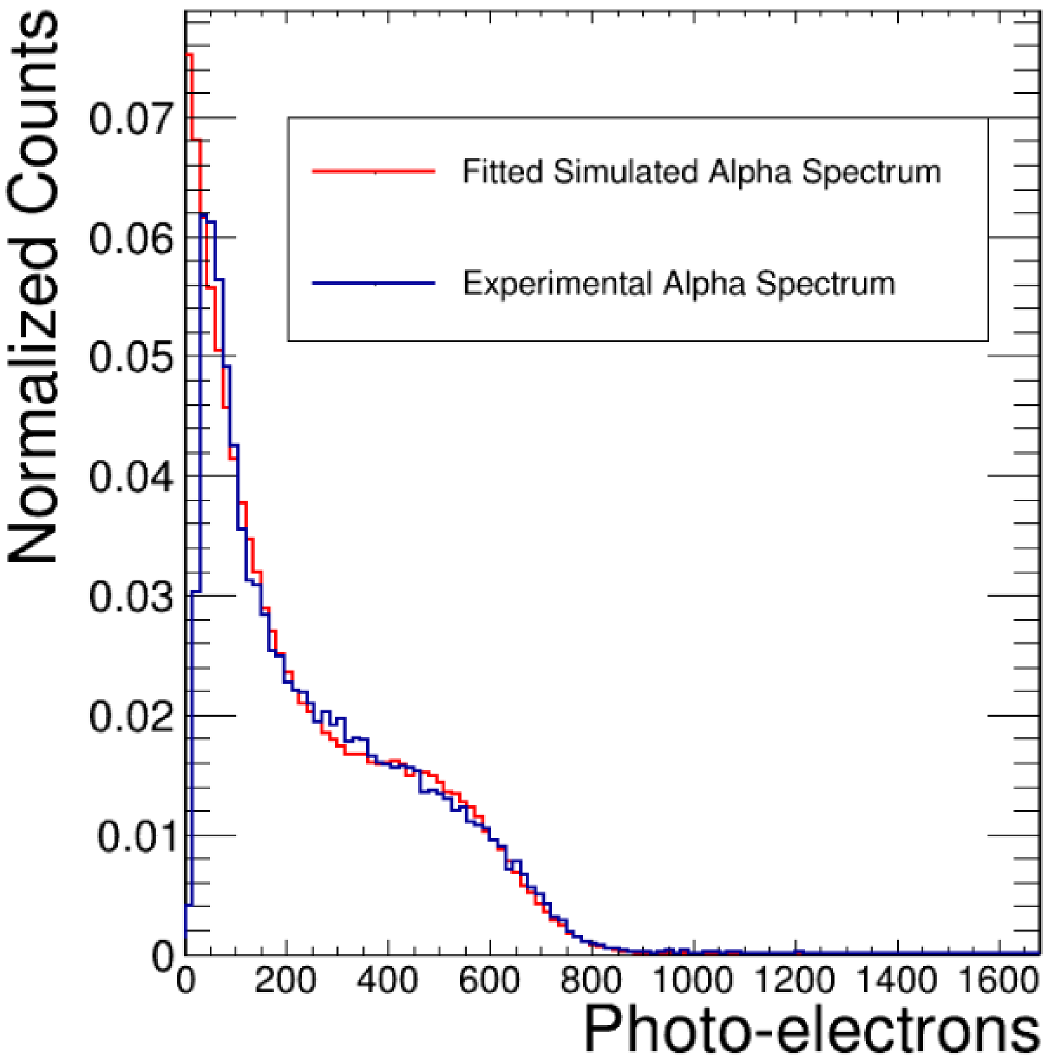
E. Segreto JINST 13 P08021 (2018)

X-ARAPUCA single sided



E. Segreto JINST 15 05, C05045 (2020)

X-ARAPUCA double sided



The DUNE collaboration, JINST 15 T08010, (2020)

Conclusions

- The **first LAr test of X-ARAPUCA** single and double sided prototypes have been performed in the **cryogenic facility of the Lab. Leptons of UNICAMP**

- Both prototypes were exposed to a well known alpha source
  - Comparing the number of detected photons with the number of photons impinging on the **X-ARAPUCA** provides an estimate the **global photon collection efficiency of the device as 3.5 ± 0.5%.**
  - For the **double-sided** version of the **X-ARAPUCA**, the global detection efficiency was found to be only **10% less than the single sided** version.

Thank you!

Support from CONACyT grant 23238 is acknowledged