

# ArCLight — A Cryogenic Large-Area Photon Detector

January 2023

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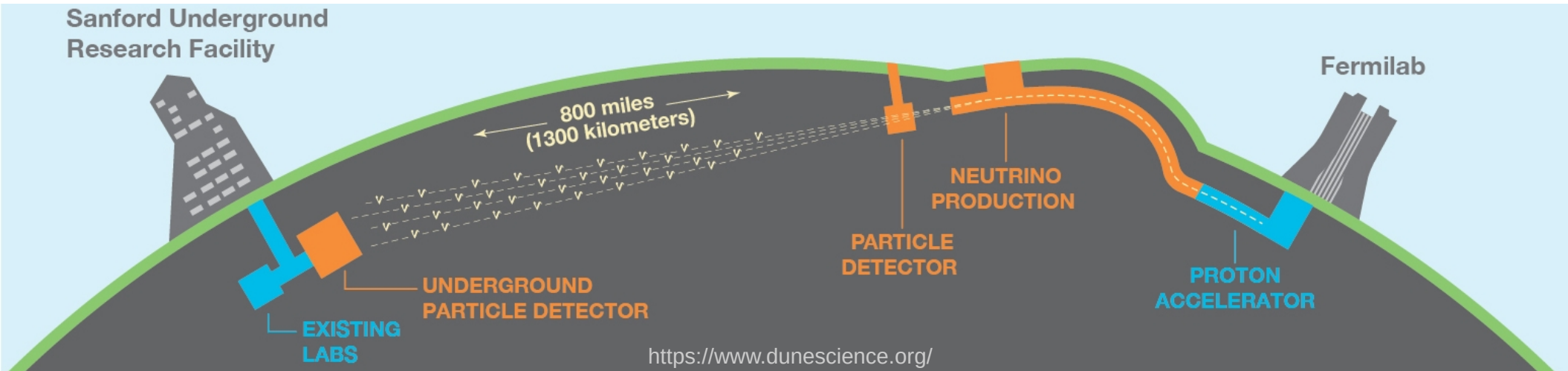
<sup>b</sup>  
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# DUNE: Deep Underground Neutrino Experiment

- DUNE is a long-baseline neutrino oscillation experiment
- DUNE will be used to define the neutrino mass hierarchy
- The new experiment will measure the leptonic CP-violating mixing phase to a higher precision

[B. Abi, 2020, Eur. Phys. J. C 80, 978]



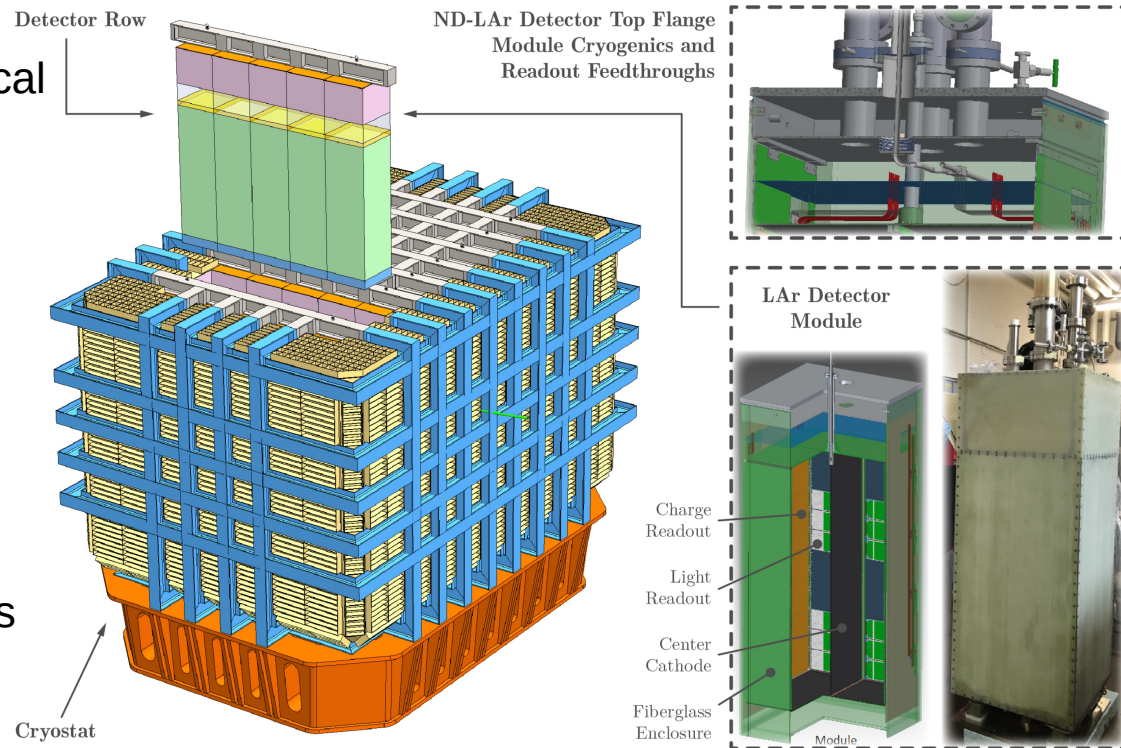
The far detector is at South Dakota

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The near detector is at Fermilab

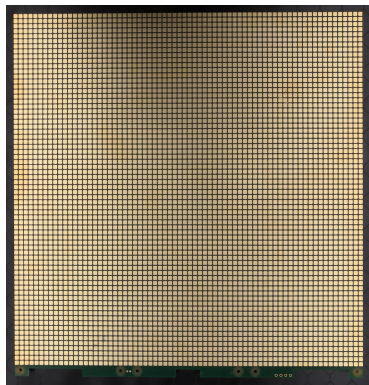
# ND-LAr: Liquid Argon Near Detector

- The ND complex consists of three detectors and one of it is the ND-LAr
- The detector is made of 35 individual and optical sealed TPC modules
- The modular build up is essential for the following reasons:
  - Short electron drift distance
  - High light spatial resolution
  - Simultaneous neutrino interactions of a beam spill can be distinguished
  - Replacing of single malfunction modules is possible

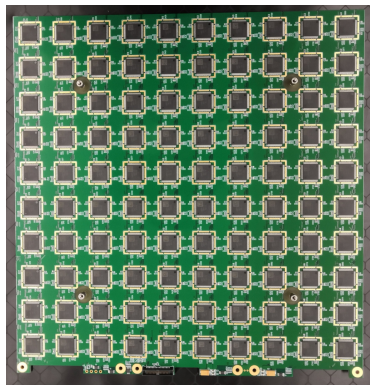


# Technologies for a modular build up

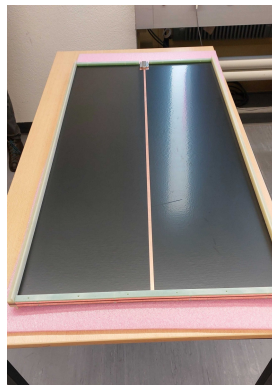
- Each module needs the following three newly developed technologies:
  - The electric field is shaped with a resistive field shell
  - The drifting electrons of the energy deposits are collected on a pixelated anode plane
  - The scintillation light is measured along the electric field with a dielectric light readout system



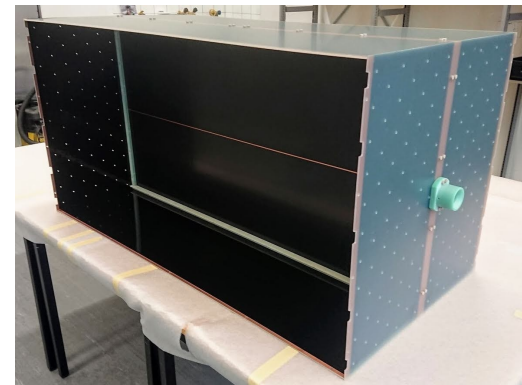
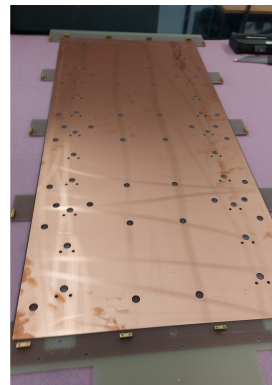
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Pixelate anode plane



Resistive field shell

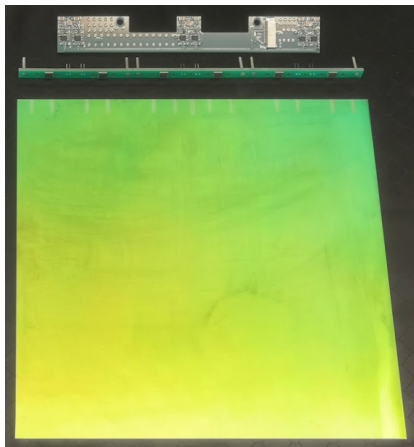




# Dielectric light detectors

- The scintillation light is collected with low-volume large-area dielectric photon detectors that are placable along side of the electric field
- Silicon photon multiplier (SiPM) detect the light of the dielectric material

Argon Cube Light (ArCLight) (Bern)

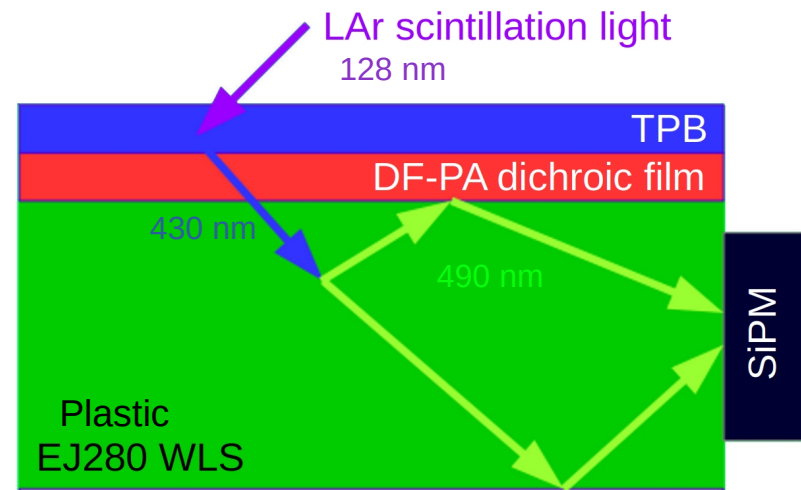


Light Collection Module (Dubna)



# Working principle of ArCLight

- ArCLight is based on ARAPUCA principle  
 [A.A. Machado and E. Segreto, 2016, JINST 11 C02004]
- 128 nm scintillation photons from liquid argon hit the TPB\* layer of ArCLight that converts the photons into the blue region (430 nm)
- The blue photons pass a dichroic film and enter a wavelength shifting plastic that shifts them into the green region (490 nm)
- Total reflection as well as the dichroic film which works as a mirror for the green photons, trap the photons in the plastic
- Six SiPMs on one edge of the plastic collect the trapped photons

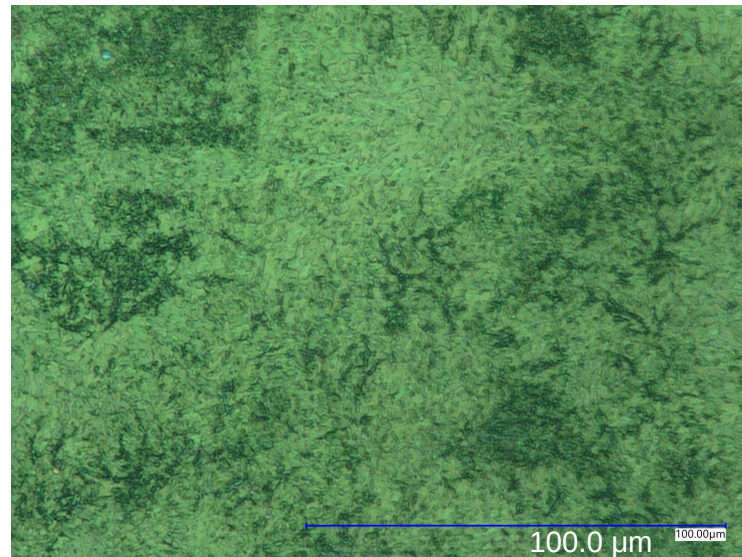


A. Abed Abud, 2021, Instruments 5, no.4, 31

TPB\*: 1,1,4,4-Tetraphenyl-1,3-butadiene

# Testing methods of ArCLight

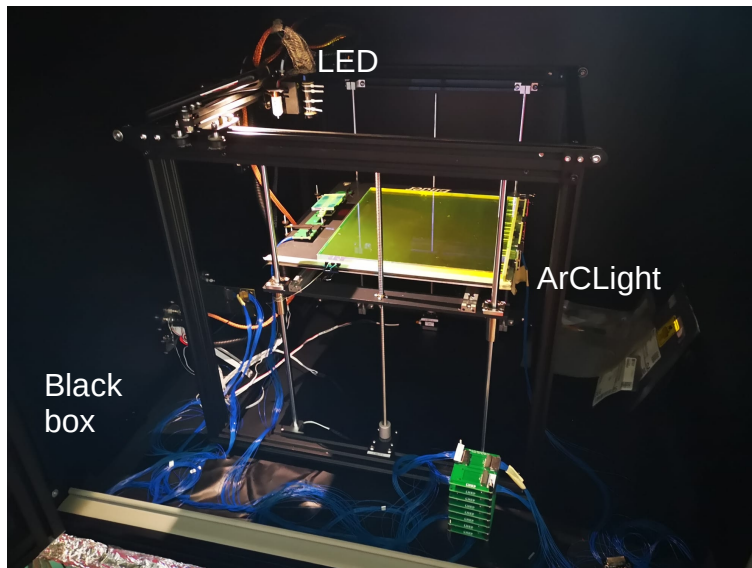
- A visual scrutiny for the coverage of TPB as well as a microscopic inspection to analyze the crystal size and shape
- The light yield response at different positions on the ArCLight coming from a LED is used to indicate the performance of the ArCLight



Microscopic view of TPB crystals of a good coated ArCLight

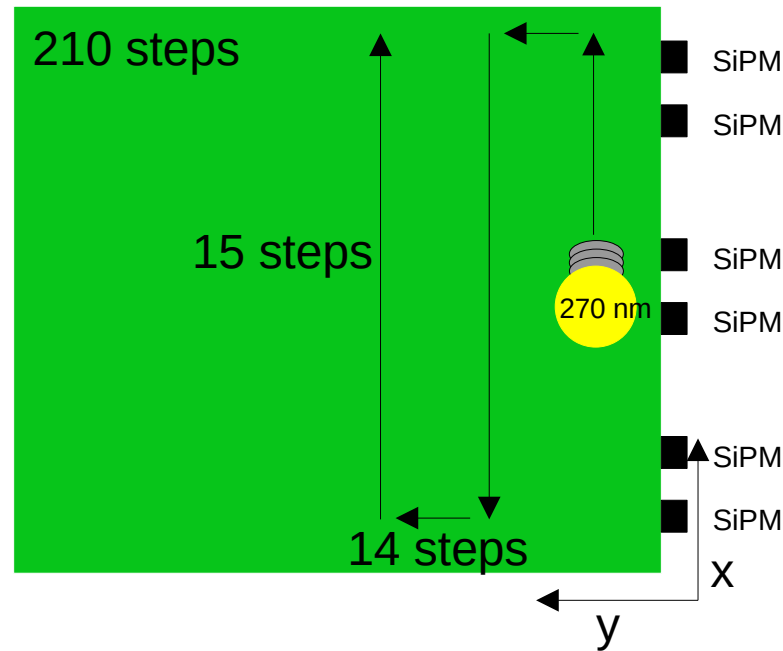
# Light yield response of ArCLight at different positions

- The light yield response of an LED at different positions on the ArCLight is used to scan it
- The scanning set-up is in a black box to reduce background light
- At every position the amount of photons per SiPM is measured



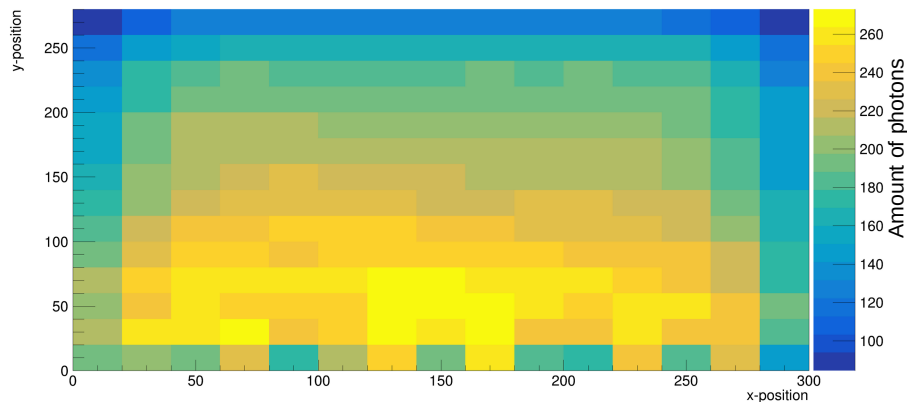
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Scan test set-up

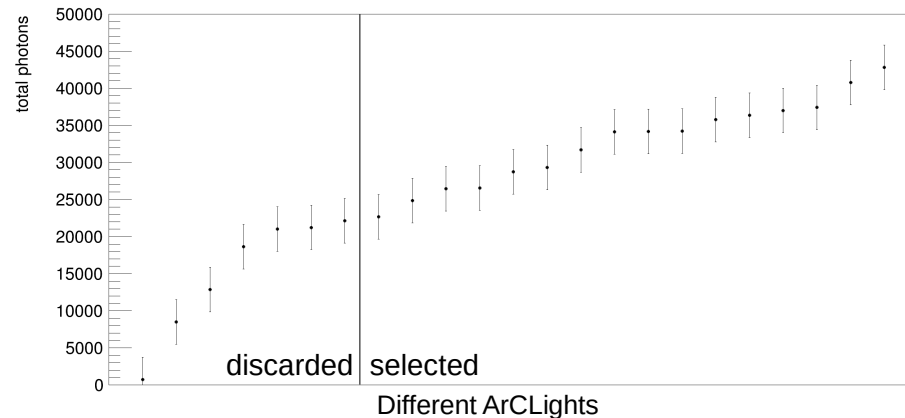


# Light yield response of ArCLight at different positions

- The total light yield collected from all six SiPMs is added up at each position to create a performing heat map of the ArCLight
- The different ArCLight are compared by adding up the photons collected from all the SiPMs at each position
- The scanning set-up creates the possibility to compare new ideas intended to improve the quality and capacity of the production and the photon detection efficiency of ArCLight



Performing heat map of an ArCLight



Comparison of the 22 ArCLight at Bern



# Summary

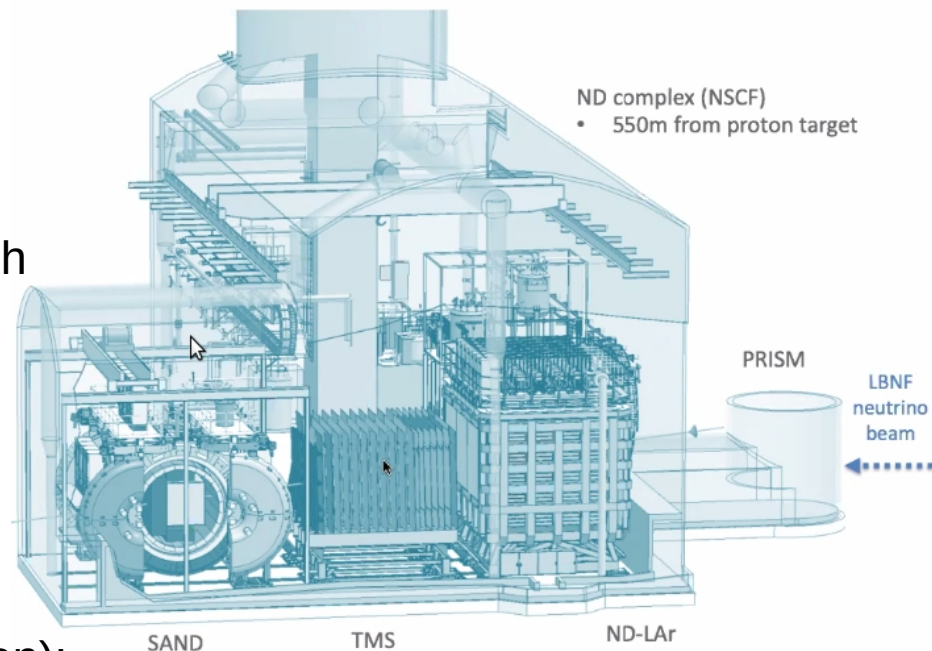
- ArCLight is an innovative small-volume light detection system based on ARAPUCA principle that is essential for the ND-LAr
- The quality of an ArCLight can be compared for different tiles by adding up the total amount of collected photons for one scan
- The qualitative comparison of ArCLight makes it possible to compare different ideas intended to improve the quality and capacity of the production and the photon detection efficiency of ArCLight

# Back-up

# Near Detector complex

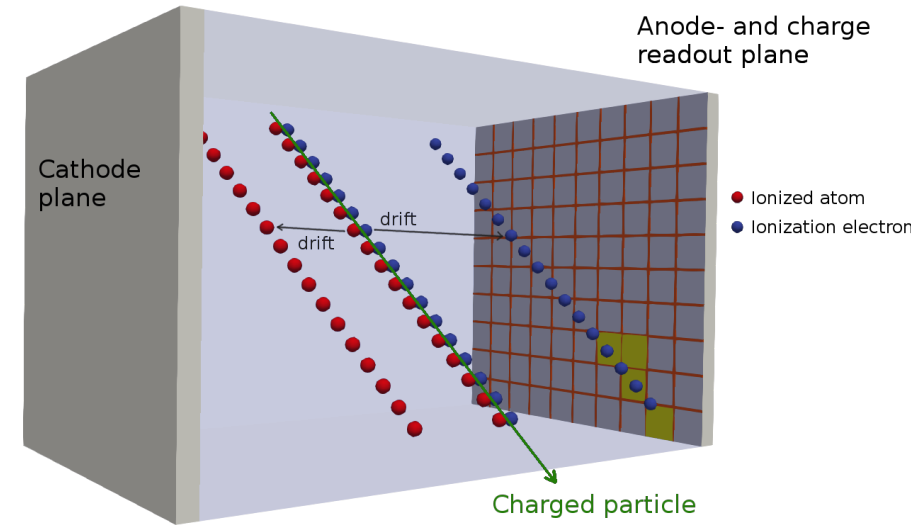
The Near Detector complex consists of three detector systems:

- The ND-Lar:
  - Is a 67-tonne liquid argon TPC
  - Has a high resolution imaging capability in high pileup environment
- The TMS (Temporary Muon Spectrometer):
  - Measures the momentum and charge of the muons
  - Will be replaced by the ND-GAr later
- The SAND (System for on-Axis Neutrino Detection):
  - Provides continuous on axis flux monitoring



# Working principle of a time projection chamber (TPC)

- Electrical charged particles ionize the argon atoms producing ionization electrons and positive charged argon ions
- An electric field drifts the electrons to anode plane where the charge read out plane is
- The interaction time is reconstructed by measuring the scintillation light of the interaction using light detectors
- The timestamp provided by the light detectors and the charge readout data provide simultaneous energy reconstruction and 3D tracking reconstruction



<https://argoncube.org/LArTPCs.html>

# Light production in Argon

