## Production and Testing of the Large-Area Photon Detector ArCLight

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### Deep Underground Neutrino Experiment (DUNE)

- DUNE is a long-baseline neutrino oscillation experiment:
  - Determination neutrino mass hierarchy
  - Measurement of the leptonic CP-violating mixing phase



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

### DUNE – Liquid Argon Near Detector (ND-LAr)

- ND-LAr is one of the three detectors in the ND complex
- ND-LAr is a modular liquid argon detector
- It consists of 35 modules
- A modular build up is needed because:
  - The electron drift distance is short
  - The light spatial resolution is high
  - It isolates neutrino interactions when more than one occurs during a beam spill
  - The single modules can be replaced in case of malfunction
- For information on the scintillation light detection performance of two ND-LAr prototype modules see Anja Gauch's talk



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## New technologies for the ND-LAr

- For the modular detector design of the ND-LAr the following technologies are developed:
  - A pixelated charge readout on the anode plane that collects the drifting electrons of the energy deposits



- A resistive field structure that shapes the electric field
- A dielectric light readout that collects the scintillation light along the electric field  $_{\rm Jan\ Kunzmann}$

## Light detectors for ND-LAr

Direct PMT readout is replaced with low-volume large-area photon detectors: Argon Cube Light (ArCLight) (Bern) Light Collection Module (Dubna)





The advantages of the two modules are that:

- Detectors can be extended along the time projection chamber (TPC) electric field as they are made of dielectric material
- Silicon photon multiplier (SiPM) readout allows a much smaller dead volume compared to traditional PMT readout Jan Kunzmann
  [M. Auger, 2018, Instruments 2, no.1, 3] 5

### Light detection with ArCLight

ArCLight is based on ARAPUCA principle

[A.A. Machado and E. Segreto, 2016, JINST 11 C02004]

- VUV scintillation photons (128 nm) are created in the liquid Argon
- TPB\* shifts the incoming photons into the blue region (430 nm)
- The plastic shifts the blue photons into green ones (490 nm)
- The dichroic film acts as a mirror for green photons, thereby trapping them
- The green photons in the plastic are collected by six SiPMs

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

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• ArCLight is built from the following materials:









Wavelength shifter plastic

1,1,4,4-Tetraphenyl-1,3-butadiene Jan Kunzmann UNIVERSITÄT BERN

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# The dichroic film is fixed on an aluminum plate

### The film is cleaned with soap

- TPB is deposited on the dichroic film in the coating chamber
- This means that the TPB is sublimated in a vacuumed coating chamber and deposited on the dichroic film
- The coating chamber is evacuated to 10<sup>-3</sup> mbar and heated up to 220°C



Coating chamber

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- The coated film is removed from the aluminum plate and glued on the front side of the plastic
- Additionally dichroic film is glued to three narrow sides to act as a reflector and increase the light yield



Coated film is removed from aluminum plate



The end product: An ArCLight

# Quality control of ArCLight production



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- Two quality control tests are used:
  - A quantitative test using LED light to scan the ArCLight measures the light yield response at different positions and shows the performance of the ArCLight
  - There is a qualitative test performed in form of a visual inspection for the overall coverage and detailed inspection with a microscope for the crystal size and shape

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- ArCLights are scanned with an LED in a black box
- The amount of photons per SiPM per step is recorded





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Scan test set-up

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Scan test set-up

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- Scan of the ArCLights
- The plot on the left shows the sum of the photons for all six SiPMs of an ArCLight per step at each position



- The sum of all photons for all steps and all positions is taken as a criteria for comparison and selection
- The plot on the right shows the performance of all the 22 ArCLights • that are in Bern at the moment Jan Kunzmann

100.0 µm

Visual tests of the ArCLights

- The shape and size of the crystals of the coated TPB
- The homogeneity of the coverage on the plate
- The size of empty spaces without TPB Jan Kunzmann

Microscopic view of TPB crystals of a good coated ArCLight

### The performance of an ArCLight depends on:





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### Conclusion



- ArCLight is an innovative small-volume light detection system based on ARAPUCA principle that is essential for the ND-LAr
- Bern currently produces ArCLights by depositing TPB on the dichroic film that is mounted on the wavelength shifting plastic
- The comparison of the total amount of photons for one scan and the shape of the crystals indicates that the performance of the ArCLights is better if there is a good coverage with irregular crystals
- R&D continues on the ArCLight to improve:
  - The quality and capacity of the manufactor
  - The photon detection efficiency

### Back-up

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### Near Detector complex

The Near Detector complex consists of three detector systems:

- The ND-Lar:
  - Is a 67-tone 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

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[A. Abed Abud, 2021, Instruments 5, no.4, 31] 21

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### **Optical adhesive**

- 3M<sup>™</sup> Adhesive Transfer Tape 9472LE
- Product features:
  - 3M<sup>™</sup> Adhesive 300LSE is a hi-strength acrylic adhesive that provides a very high bond strength to most surfaces.
  - Excellent bond to low surface energy plastics such as polypropylene and powder coatings.
  - Excellent adhesion to lightly oiled surfaces typical of machine parts.
  - Thickness range of 2.3, 3.6 and 5.2 mils for use on smooth, or rough surfaces



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