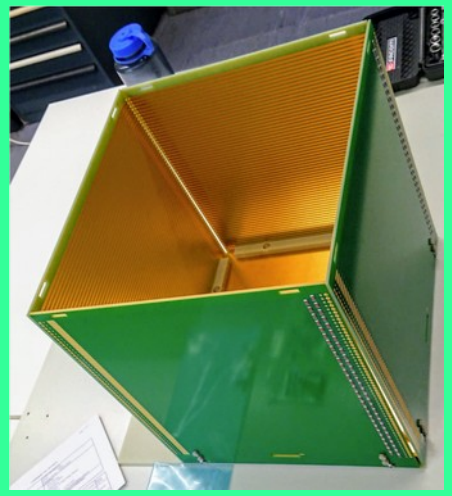
ArgonCube

ND-LAr prototypes : from small to medium

Status of the test run data analysis

contributed by many members of the Consortium !



I. Kreslo, Uni-Bern for ND-LAr consortium, 9 Dec 2020

ND-LAr TPC : ArgonCube concept

Advanced Light Readout:
- LCM and ArCLight dielectric light traps
- Enables high-coverage scintillation light detection

Pixel Charge Readout:
- LArPix ASIC and Integrated Pixel Tile
- Enables true 3D ionization charge readout

Resistive Field Cage:
- High-resistivity film as continuous resistive field cage
- Enables low-profile field cage

Modular TPC Design:
- All fiberglass (G10) LArTPC structure
- Enables optical segmentation

ND-LAr TPC : Prototyping plan overview

Component prototyping - done

Integrated system prototyping:
1-tile “Single Cube” TPC
Module 0 of the ArgonCube 2x2 Demonstrator

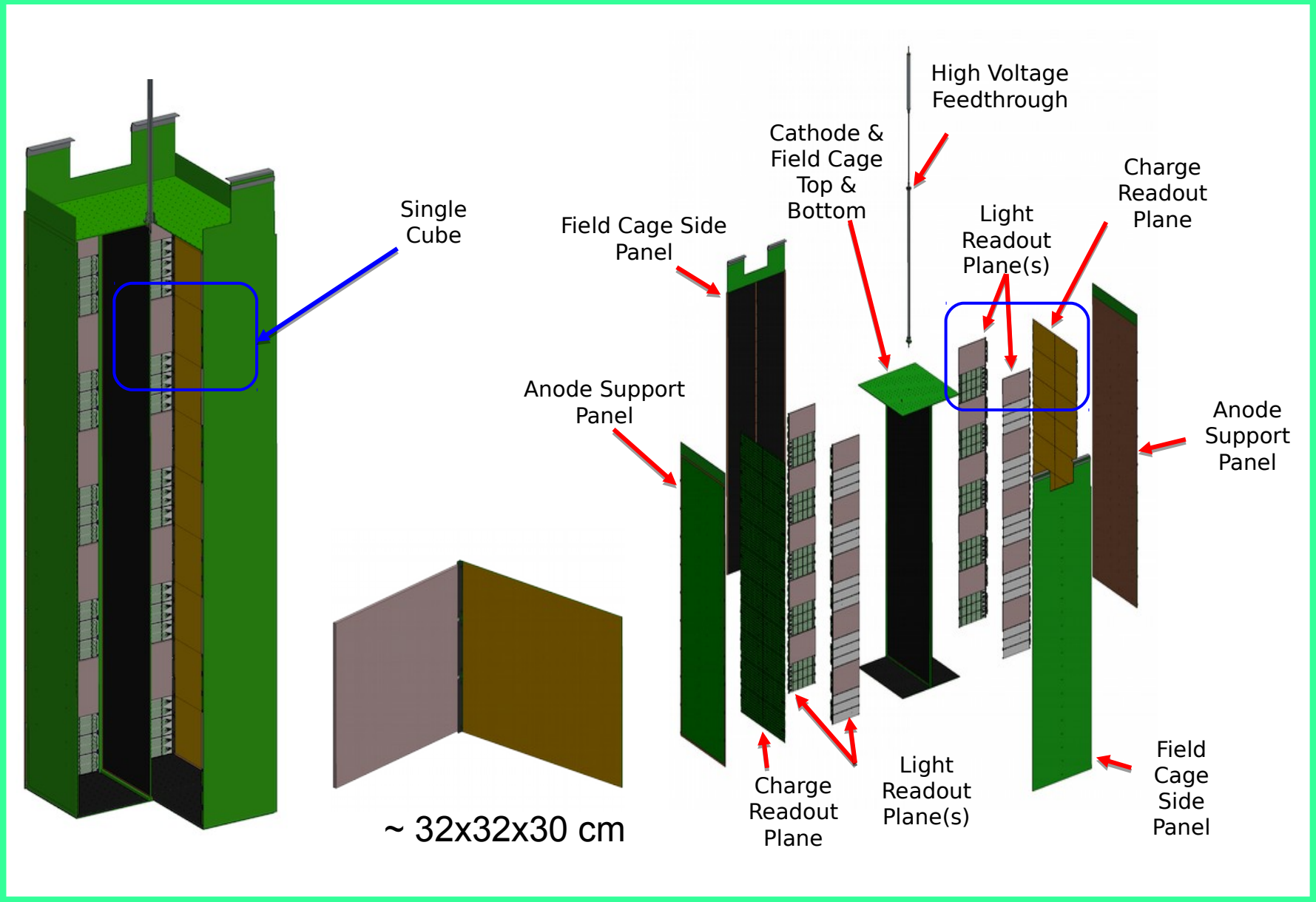
Physics Prototyping

- ArgonCube 2x2 Demonstrator @ NuMI

Engineering/Production Prototyping

- Future Full-scale Demonstrator Program

ND-LAr TPC : building elements



SingleCube TPC

Production-scale pixel tile (32 x 32 cm^2, 4.9k pixels 4.4 x 4.4 mm^2, 100 ASICs)

Production-scale ArCLight scintillation light trap (30 x 28 cm^2)

Same system interfaces as 2x2 Demonstrator

Same 30-cm drift as 2x2 Demonstrator (3/5 of ND)

Liquid Argon cooling/purification system of 2x2 Demonstrator

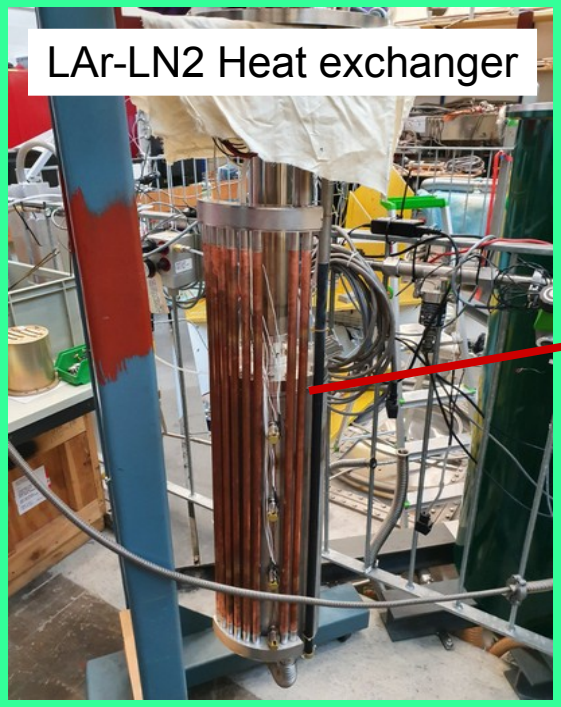
Semi-classic field cage (discrete resistors, R=1.5 GOhm)

SingleCube Cryogenics and LAr management

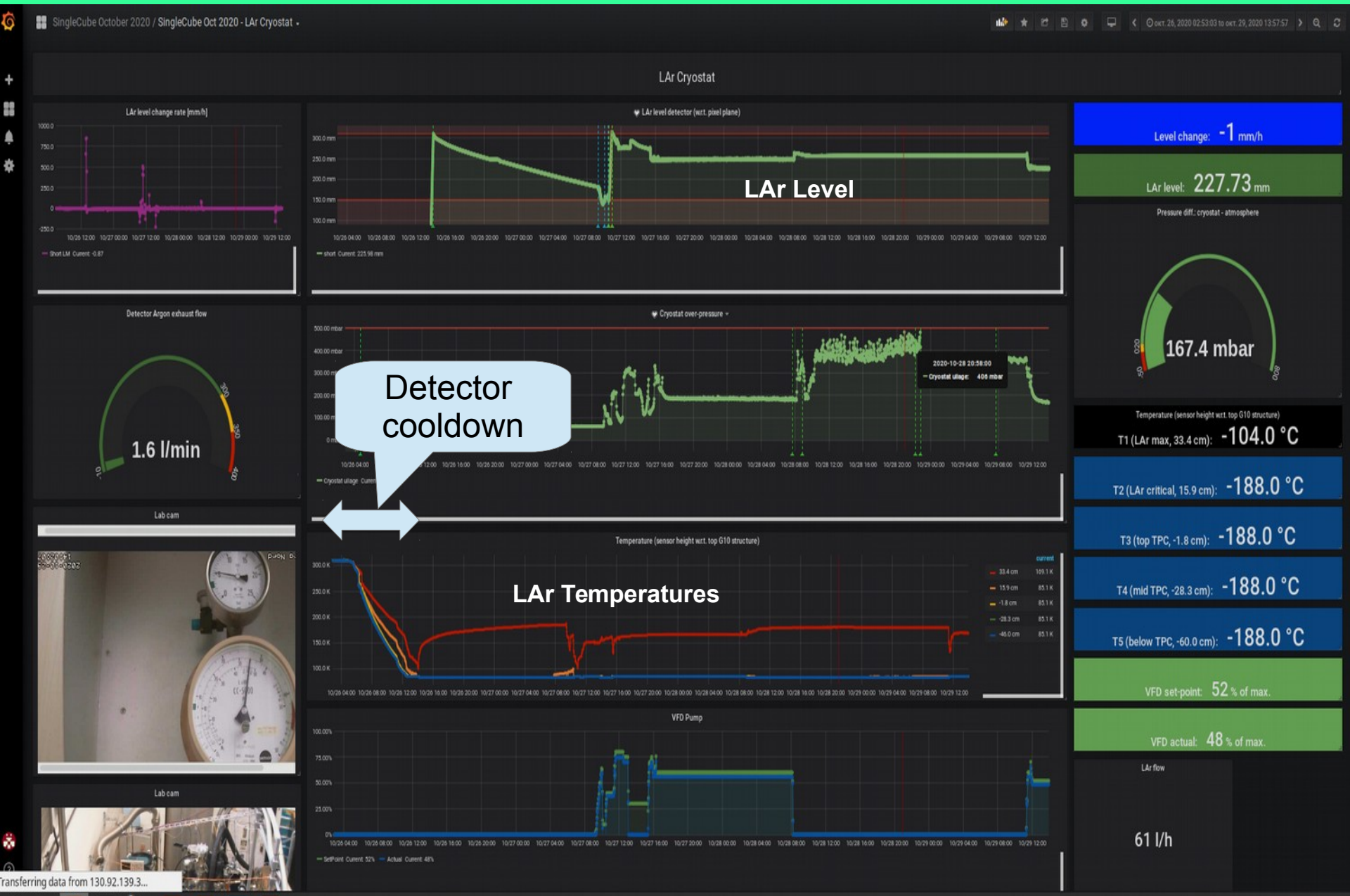
LAr recirculation rate ~100-300 l/h

Small immersed BN turbo-pump

Cooled by pressurized LN2



SingleCube TPC: test timeline



SingleCube TPC: test timeline

SingleCube TPC: test timeline

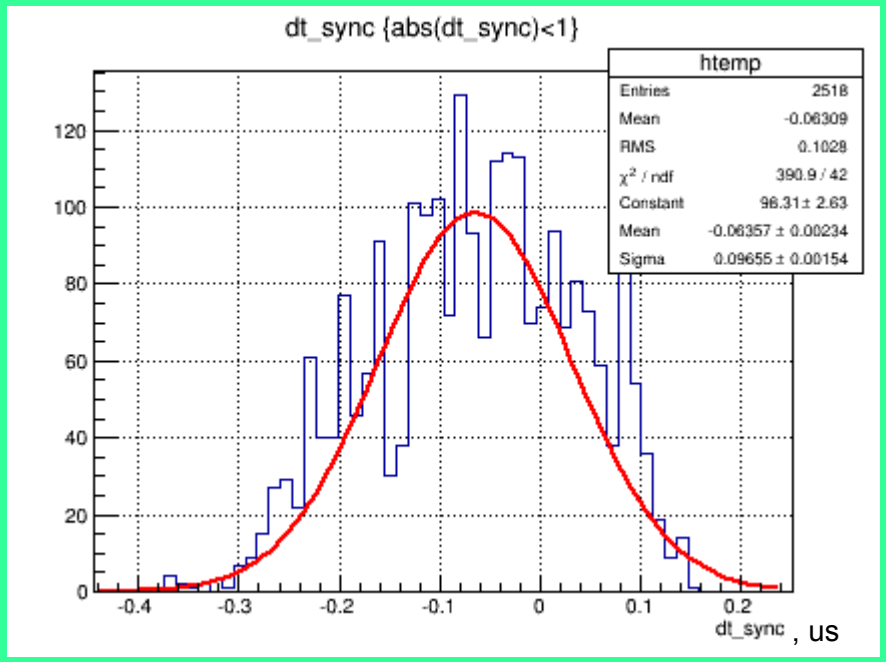
SingleCube TPC: test timeline

SingleCube TPC: test timeline

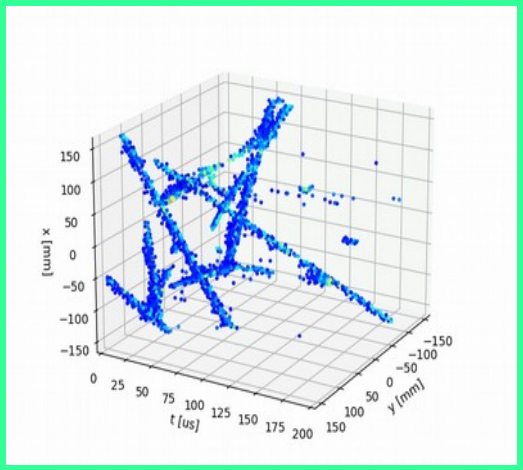
SingleCube TPC: muon tracks

>90 GB of data with drift field 0 to 1kV/cm

Event marker from ArCLight to LArPIX



Light readout
6xSiPMs, VME ADC
Triggered on threshold, send event marker pulse
Time stamp (l_usec_ts)



Charge readout 100x LArPIX + PACMAN
Self-triggered, time-stamped

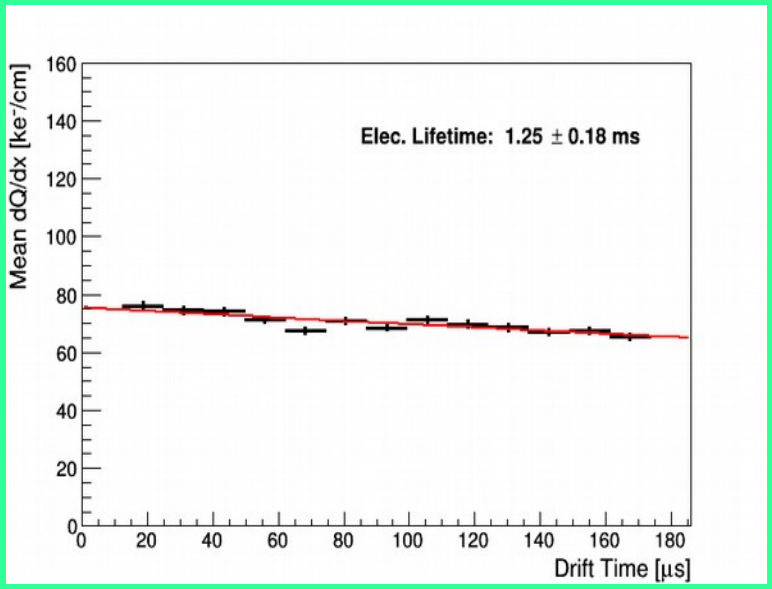
event marker pulse, time-stamped in PACMAN (t_usec_ts)

Single Cube TPC: muon tracks, LAr purity

3D LArPix data -> reconstructed track

Select cathode-anode crossing muon tracks (start/end cut)

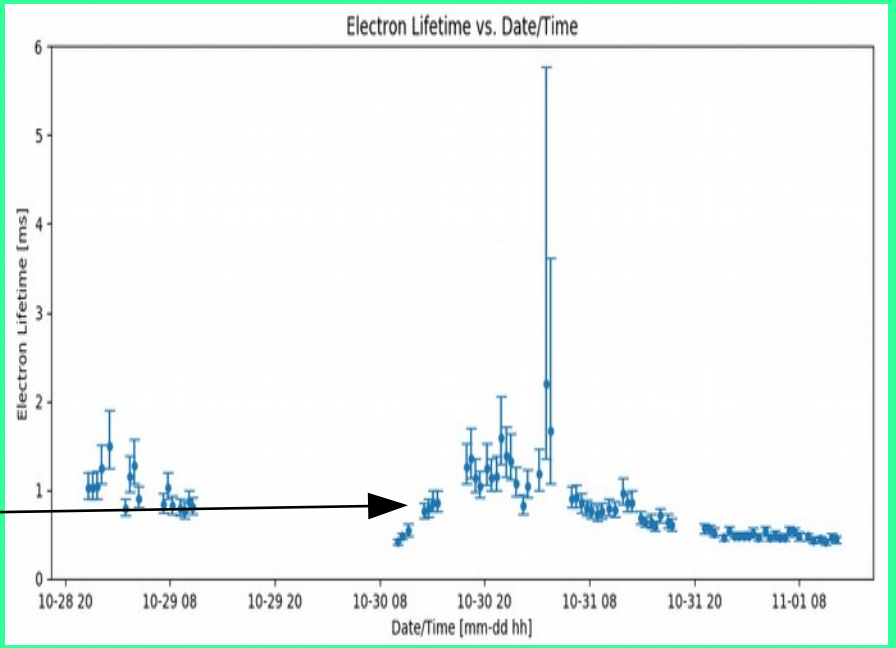
Plot LArPix hits amplitude vs drift time



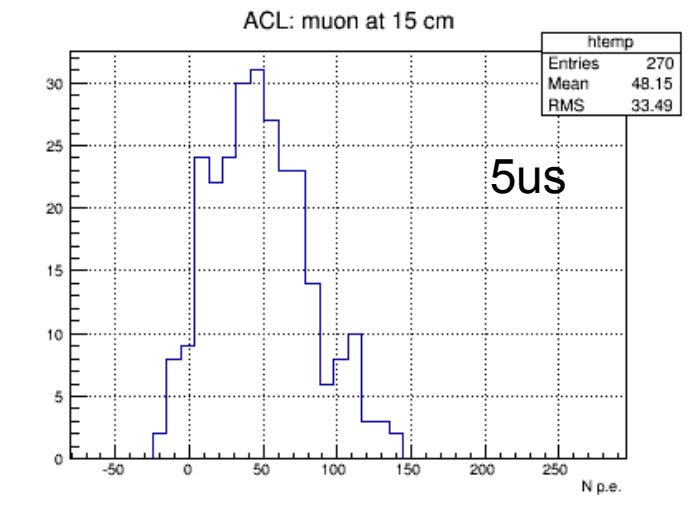
Achieved 500 us electron lifetime target

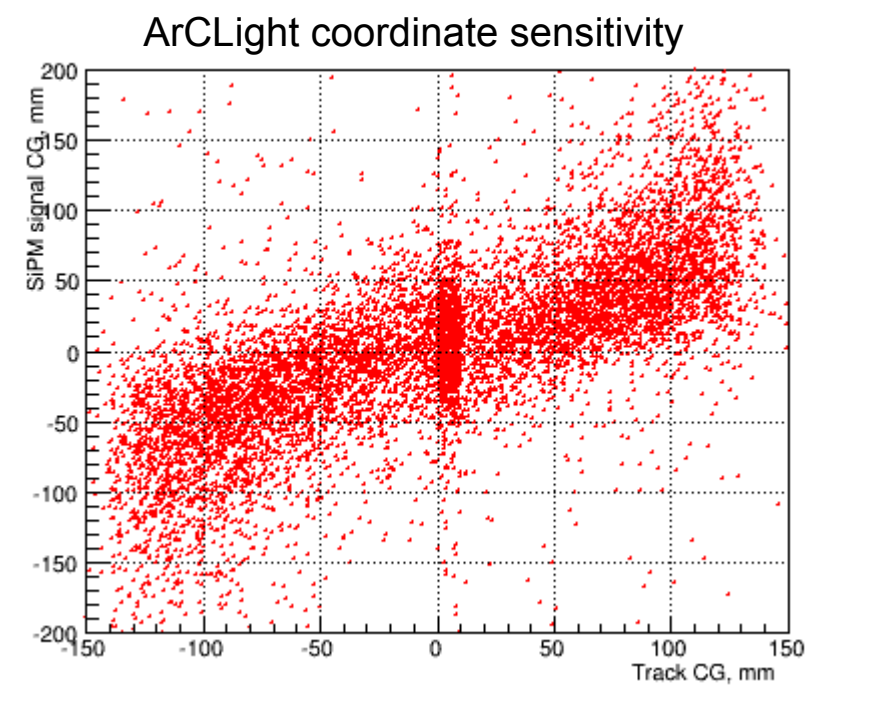
Slowly degrades during periods of data collection

Quickly recovered by recirculation

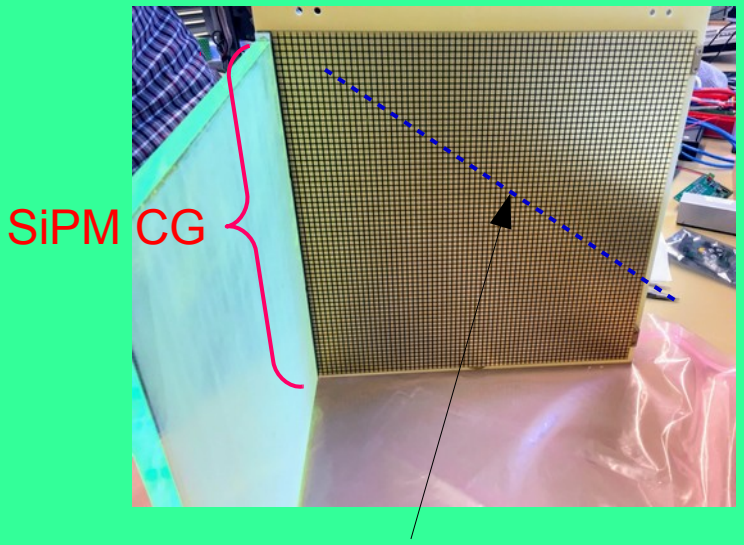


SingleCube TPC: muon tracks, ArCLight @0.5 kV/cm





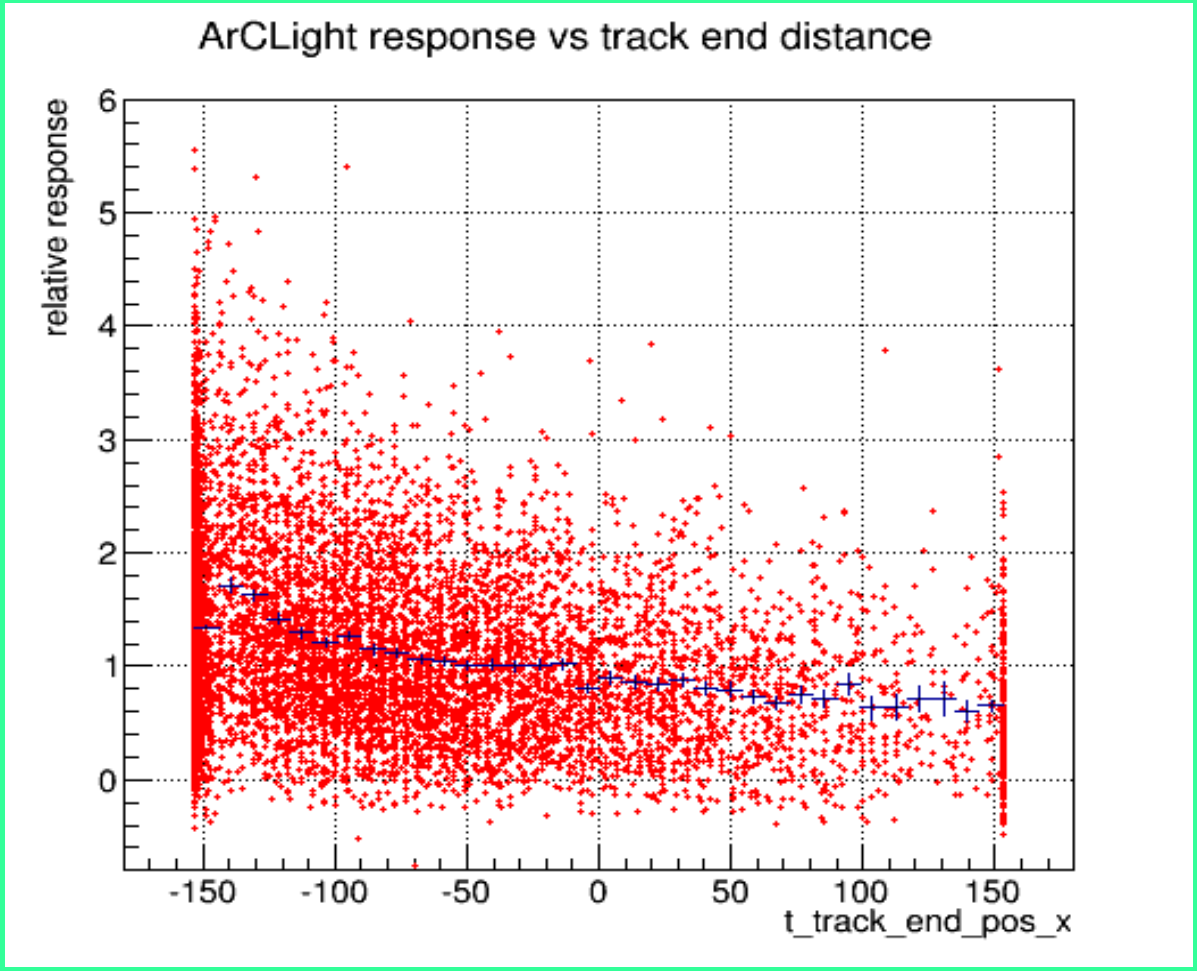
Simplest coordinate-extraction algorythm:



Observed correlation between charge location and ArCLight signal distribution over SiPMs

SingleCube TPC: ArCLight direct muon track crossing response

ArCLight located at x=-152 mm



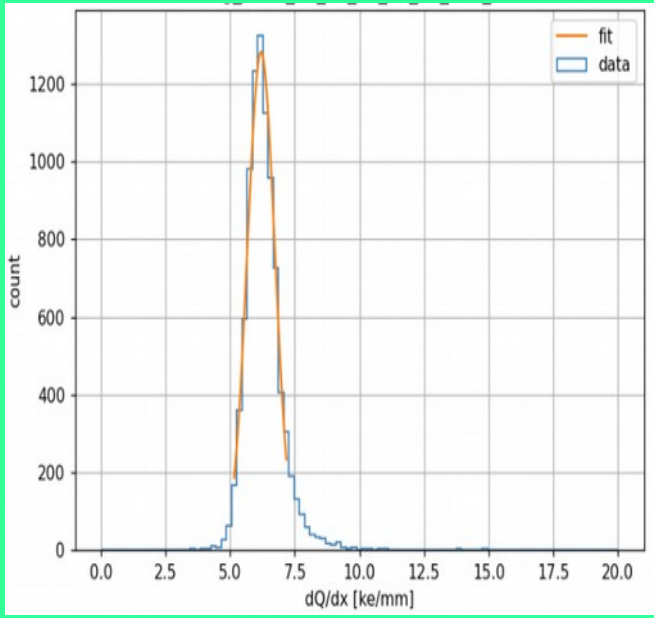
SingleCube TPC: muon tracks, charge yield @0.5 kV/cm

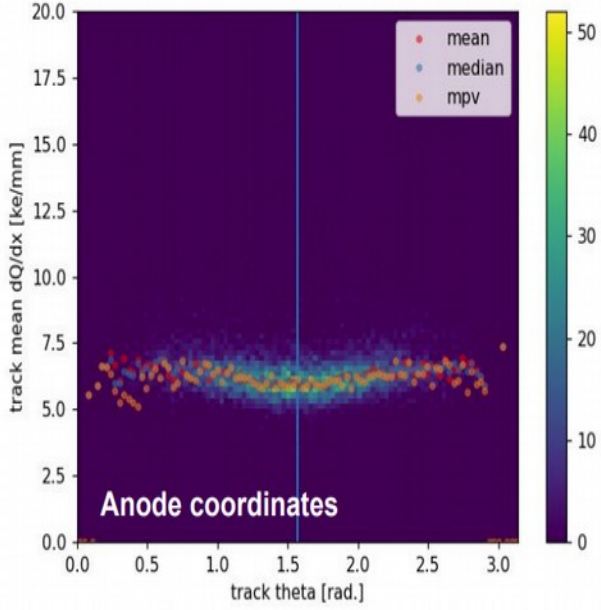
Charge Measurement:

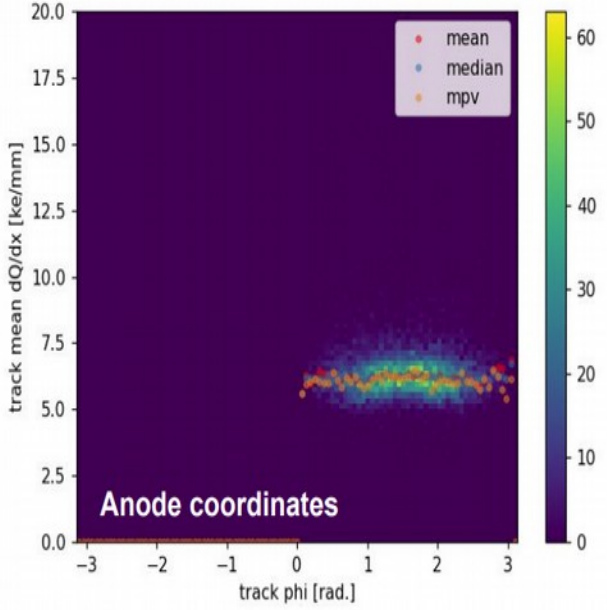
- Select cosmic muon tracks
- Apply correction for drift loss, based on electron lifetime measurements
- Examine track charge relative to track length: dQ/dx

Preliminary Results:

- Observed charge stable and consistent with expectation
- Minor variation in dQ/dx with orientation of track relative to LArPix anode

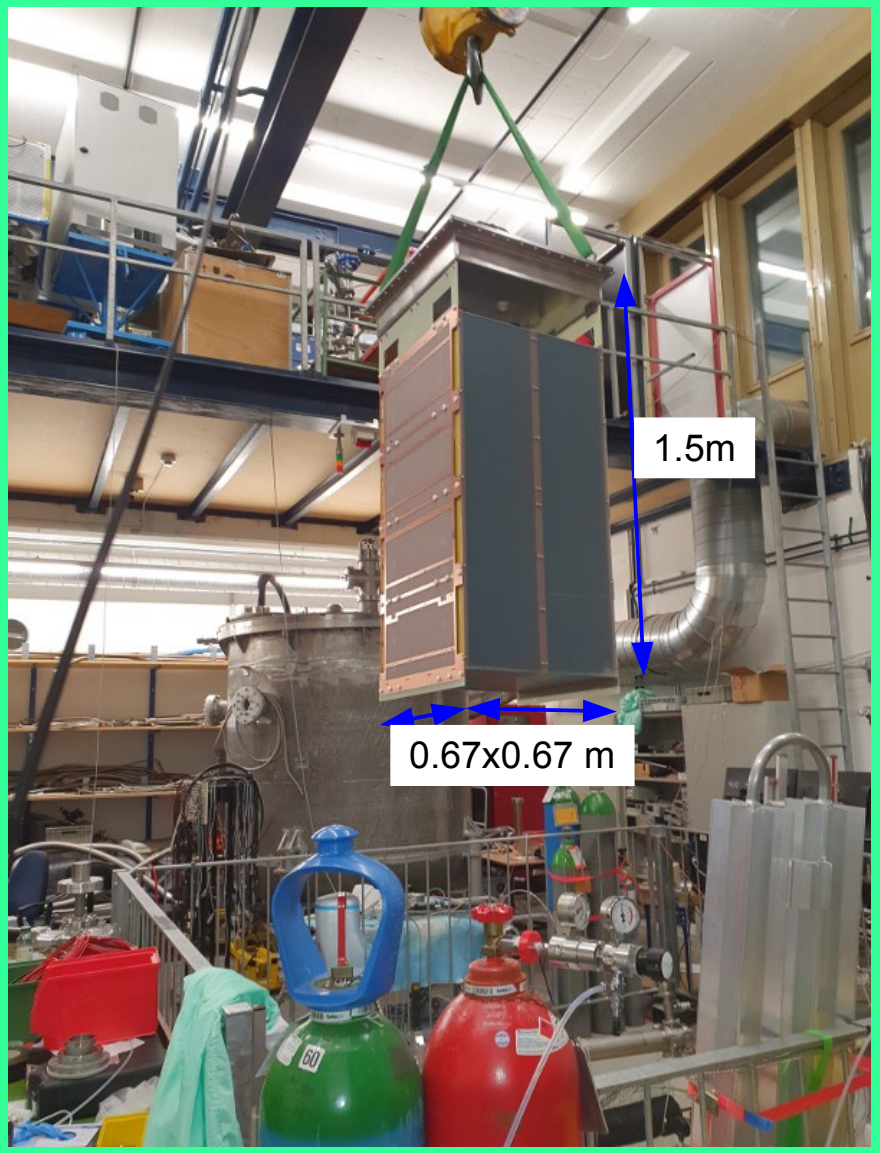


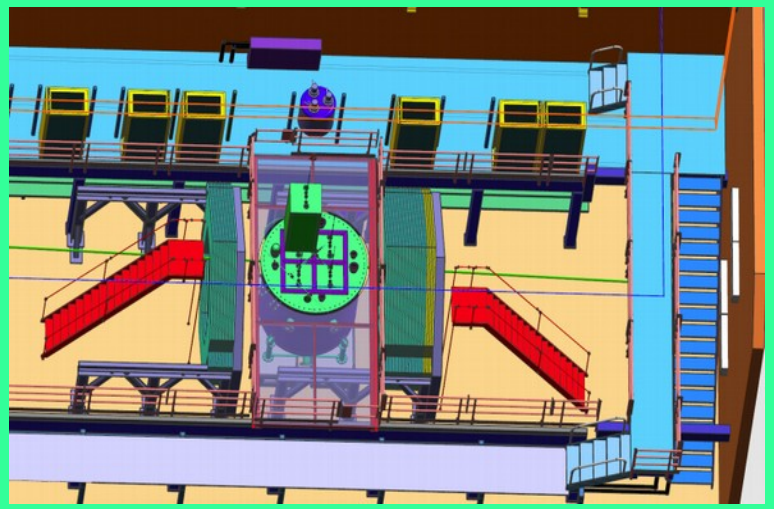




ArgonCube

SingleModule TPC - building block for 2x2 Demonstrator





SingleModule TPC - building block for 2x2 Demonstrator

Production-scale pixel tile (32 x 32 cm^2, 4.9k pixels 4.4 x 4.4 mm^2, 100 ASICs)

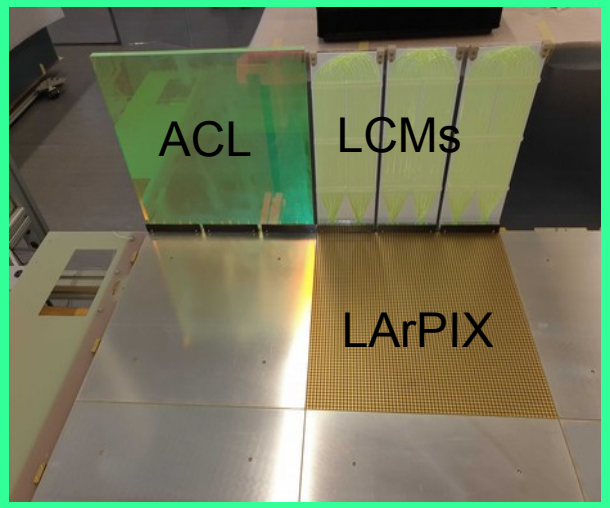
Production-scale ArCLight + LCM for light readout

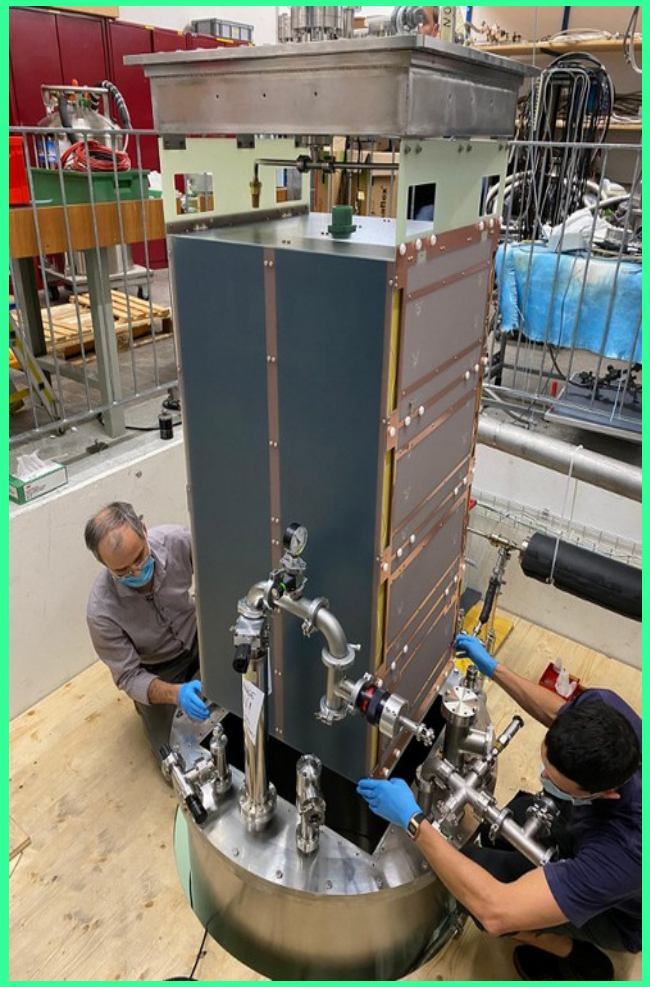
2x2 Demonstrator system interfaces

30-cm drift of 2x2 Demonstrator (3/5 of ND)

Liquid Argon cooling/purification system of 2x2 Demonstrator

Resistive field shell, R = 71 MOhm @0.5 kV/cm @90K





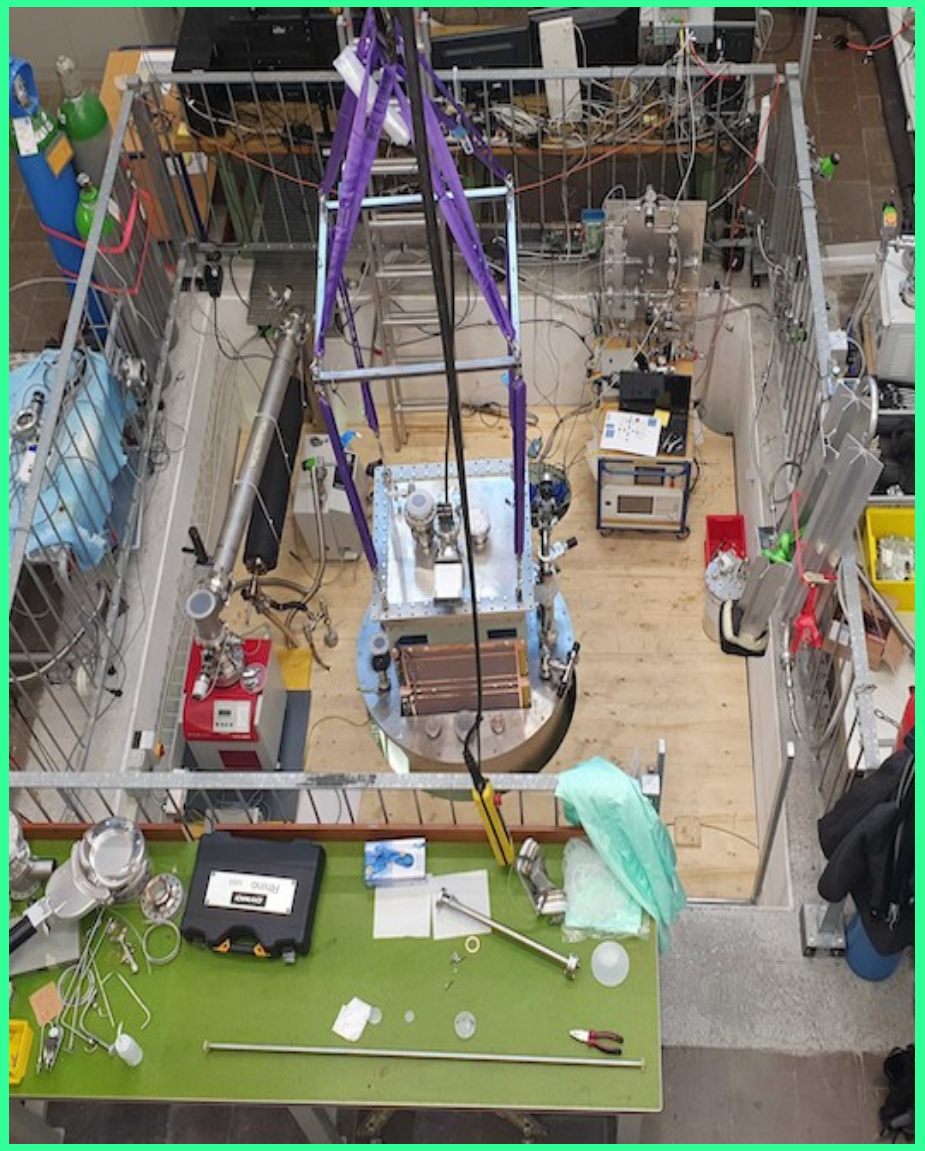
ArgonCube

SingleModule Cryogenics and LAr management

LAr recirculation ~100-300 l/h

Small immersed BN turbo-pump

Cooled by pressurized LN2



ArgonCube

SingleModule Test timeline

17 Nov - 20 Nov: evacuation of the detector, leak fixing, residual P=8.6e-5 mbar

20 Nov - 22 Nov: purge with warm argon

22 Nov - 23 Nov: purge with cold argon (mild rate cooldown)

23 Nov - 24 Nov: cooldown

24 Nov: start of DAQ, calibrations

25 Nov: HV @ 0.5 kV/cm

26 Nov: HV @ 0.7 kV/cm

27 Nov: HV @ 0.75 kV/cm

28 Nov: HV @ 1.0 kV/cm

1 Dec: last data run, start emptying detector

3 Dec: Detector is at room T, 24-h shifts are finished.

SingleModule HV- stability

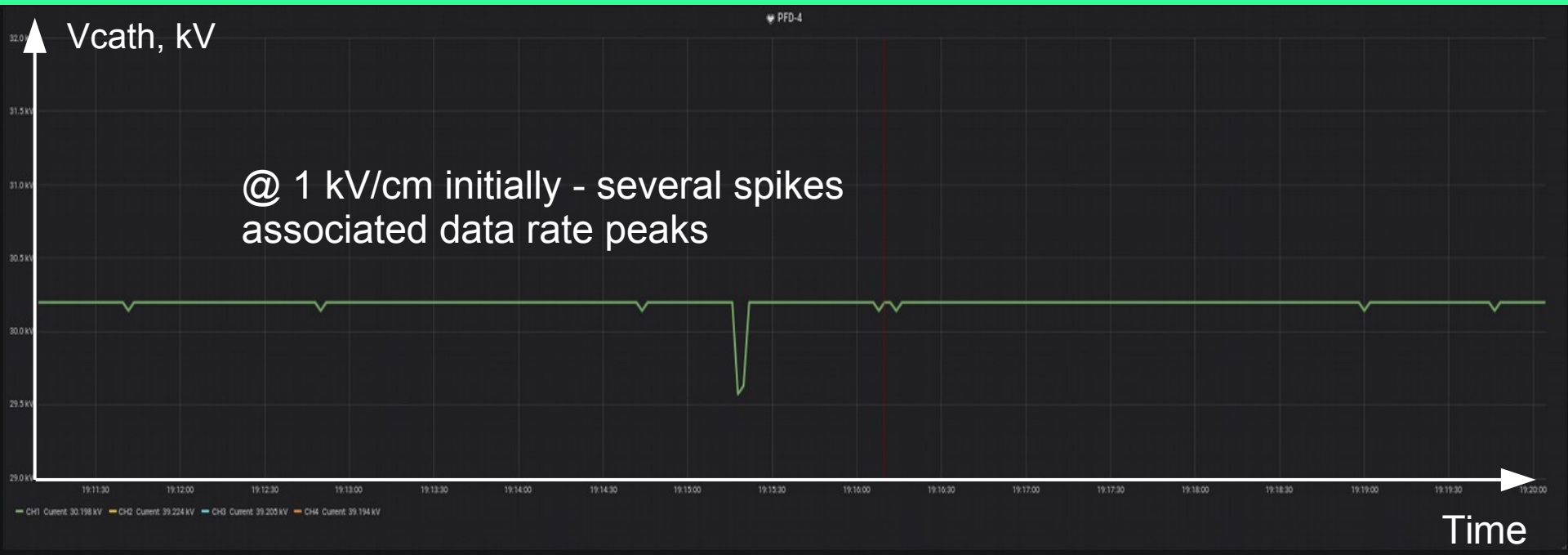
~ 48h at 0.5 kV/cm (Nominal field)

~ 24h at 0.75 kV/cm

~ 24h at 1.0 kV/cm - several short (~5min) instabilities observed at the beginning (HV conditioning of the field shell?)

SingleModule HV- stability and data rate

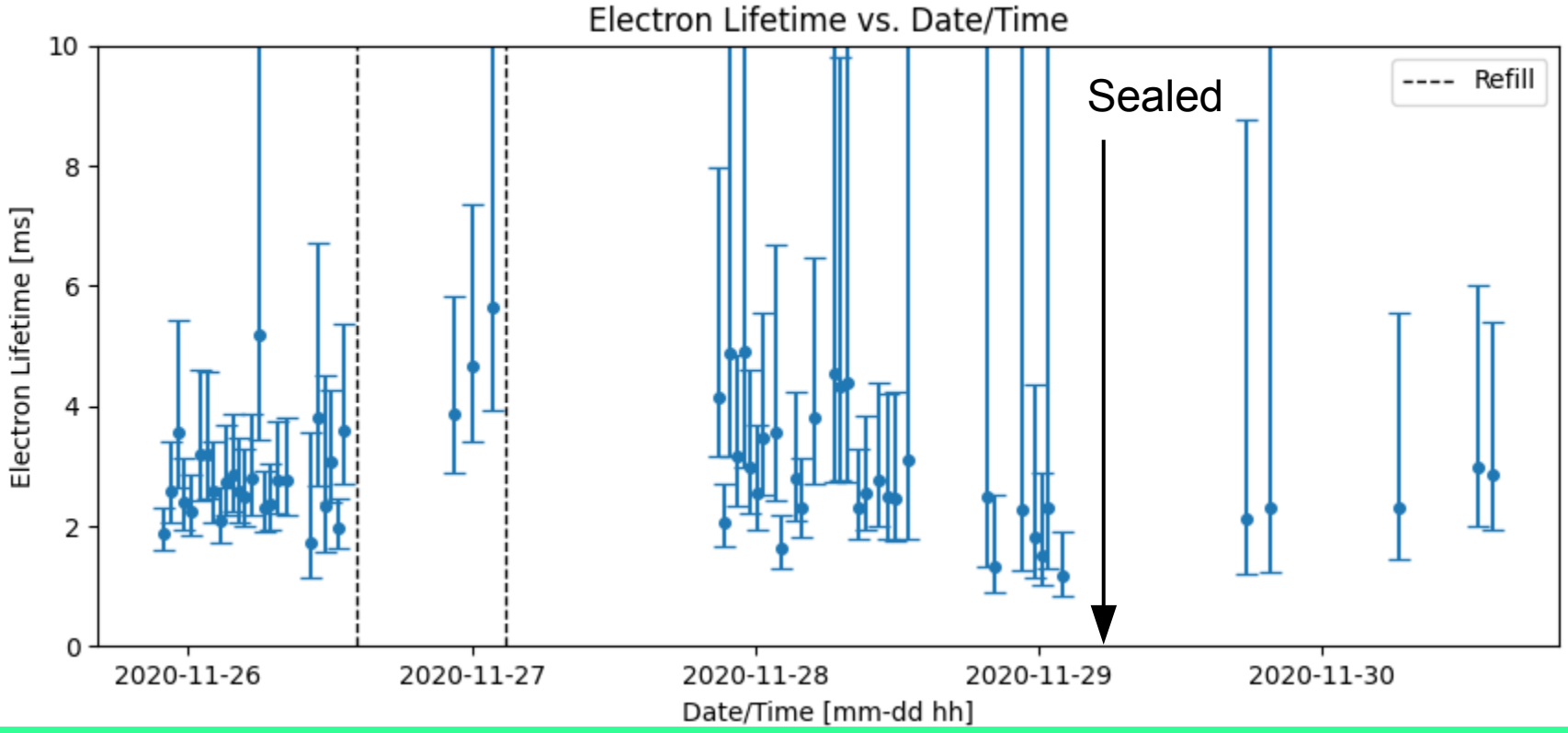
Elevated field - twice the nominal



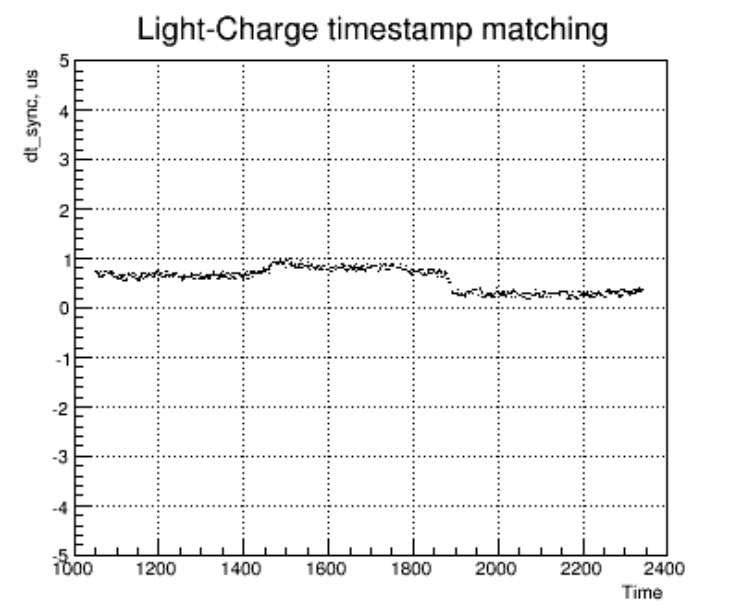
SingleModule LAr purity

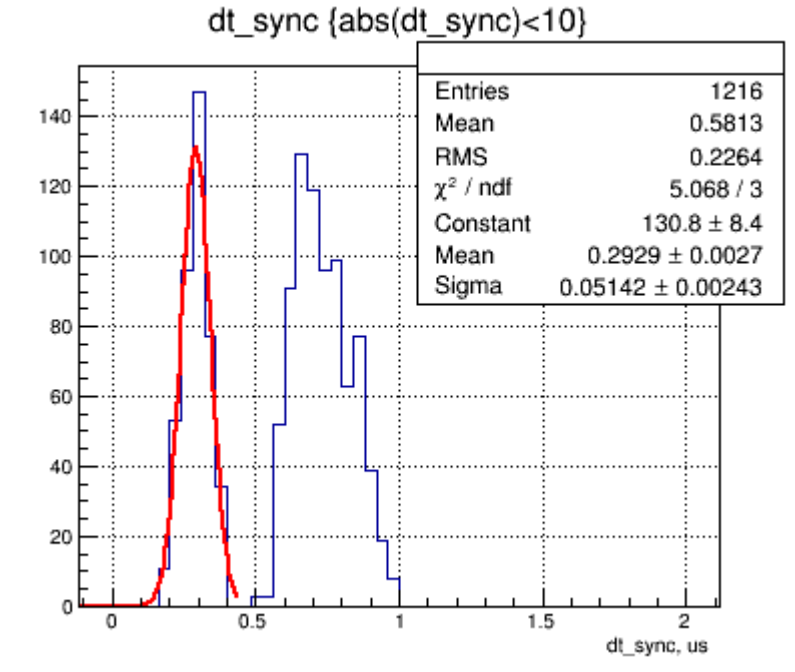
> 2 ms lifetime is achieved in both modes:

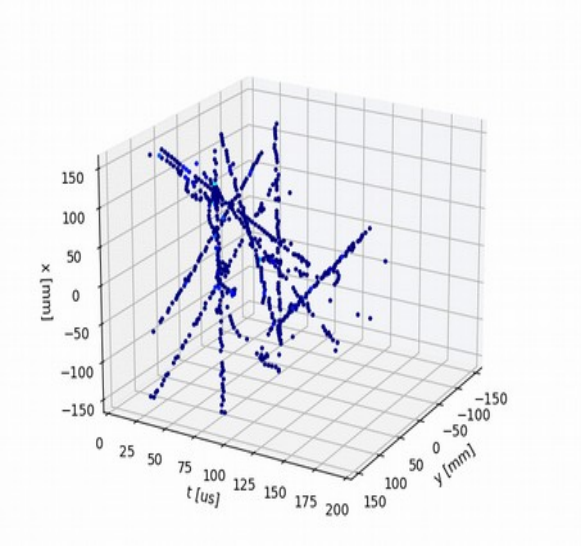
- Sealed detector at ~400 mbarg, continuous recirculation
- No recirculation, exhausting LAr at a rate of 65 slpm GAr (level loss ~0.5 cm/h)

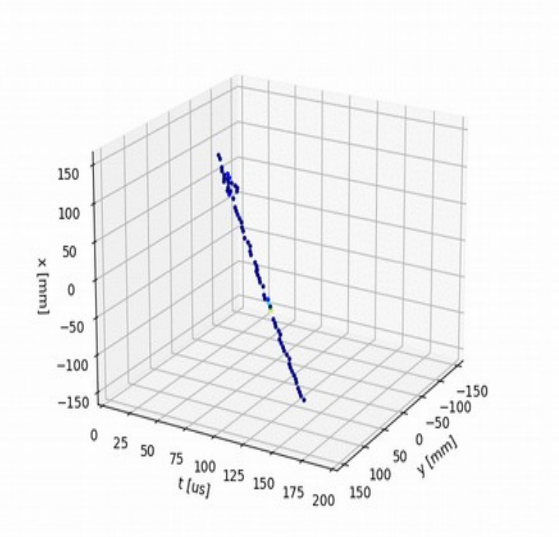


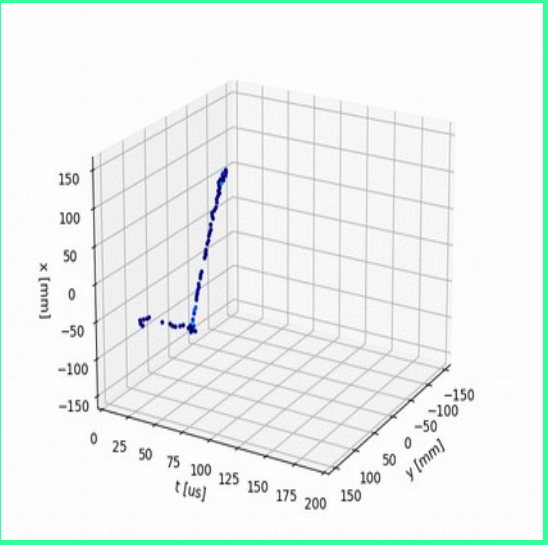
SingleModule reconstructed tracks



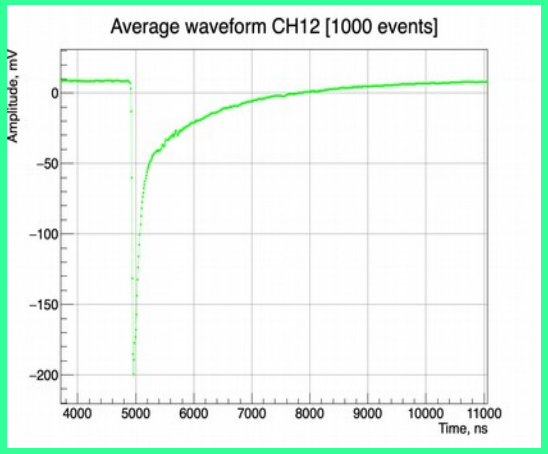




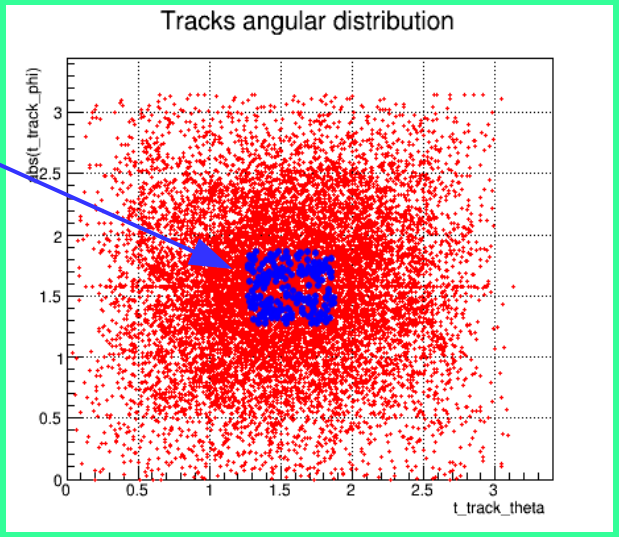




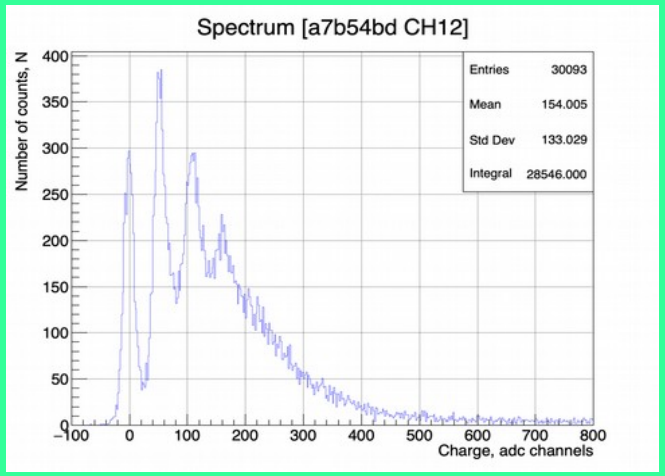
SingleModule Light Detection System performance

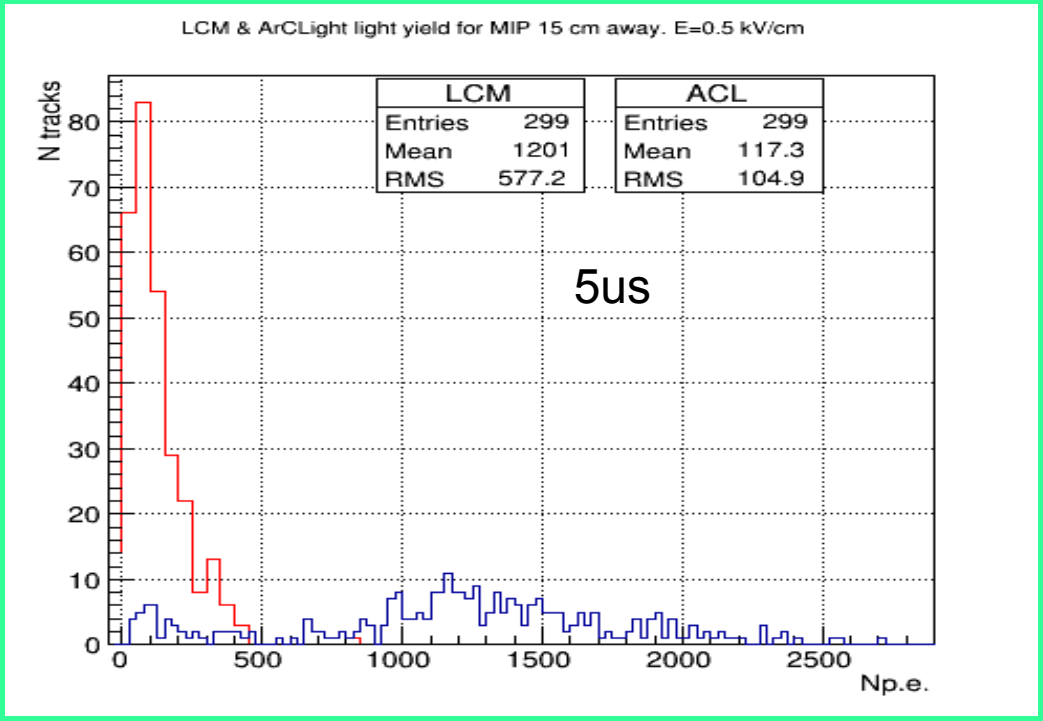


Selection of vertical MIPs



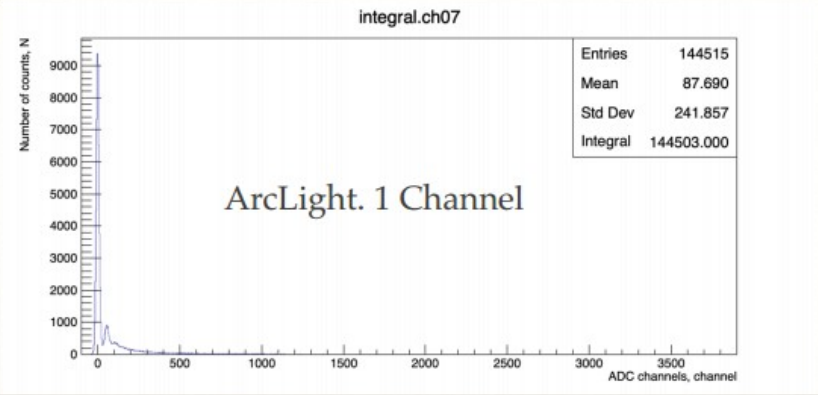
Calibration : ~ 50 ADC/p.e.

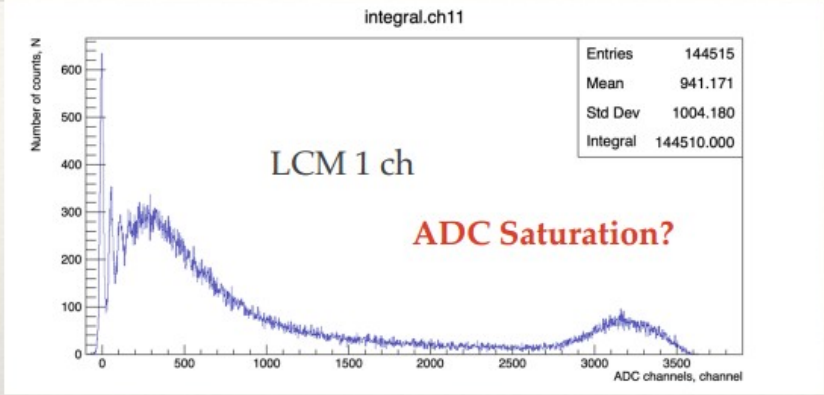




SingleModule : Light detecton system

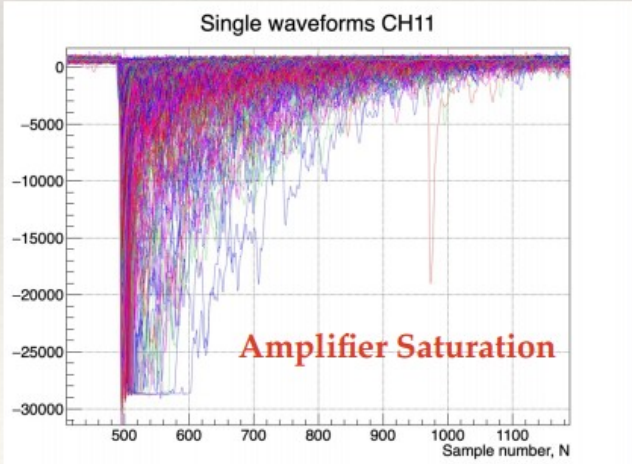
Amplitude/charge response (80 ns)





ACL		LCM	
ch	Mean	ch	Mean
2	100.148	9	666.753
3	113.801	10	714.445
4	91.295	11	941.171
5	97.602	12	925.278
6	88.499	13	922.92
7	87.690	14	935.248
	579.035		5105.815

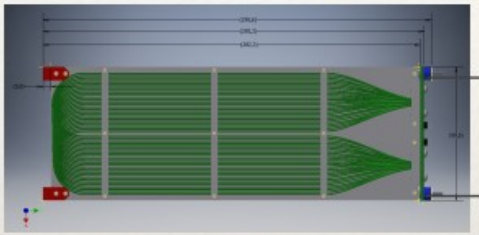
PDE_{LCM}/PDE_{Arc} ~ 10 (?) Tracks are very needed!!!



SingleModule : Light detecton system

Time resolution (Threshold)

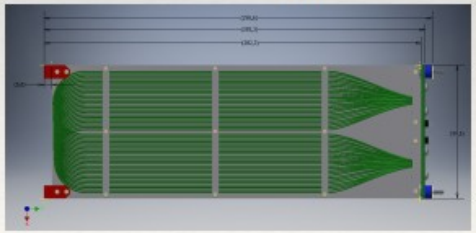
Bis-MSB coating



T1

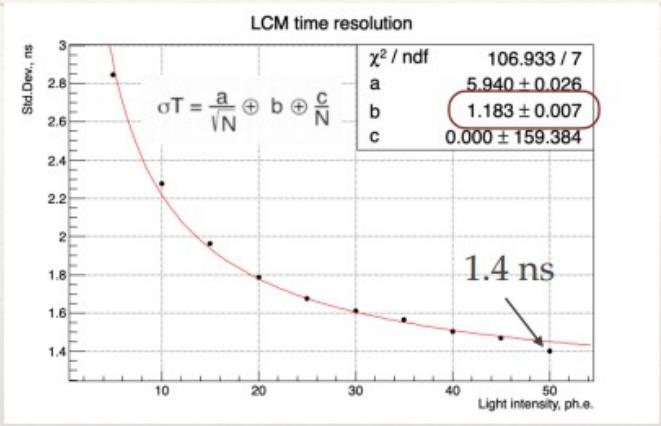
T2

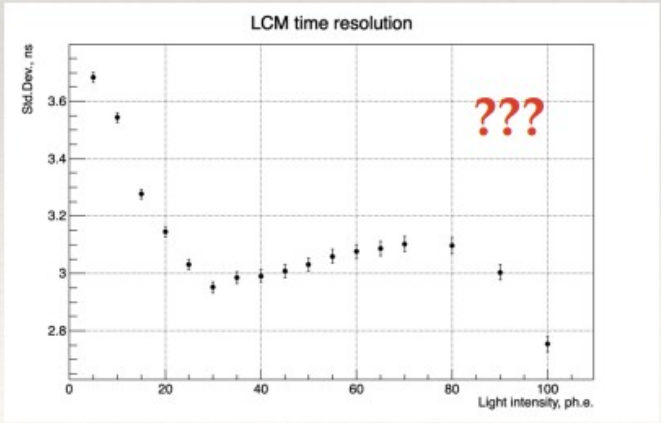
TPB coating



T1

T2

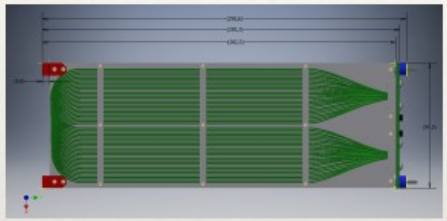




SingleModule : Light detecton system

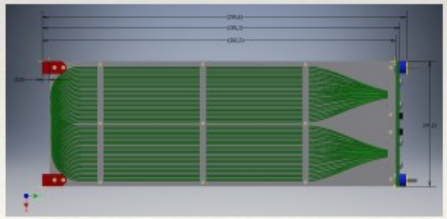
Time resolution (Slicing)

Bis-MSB coating

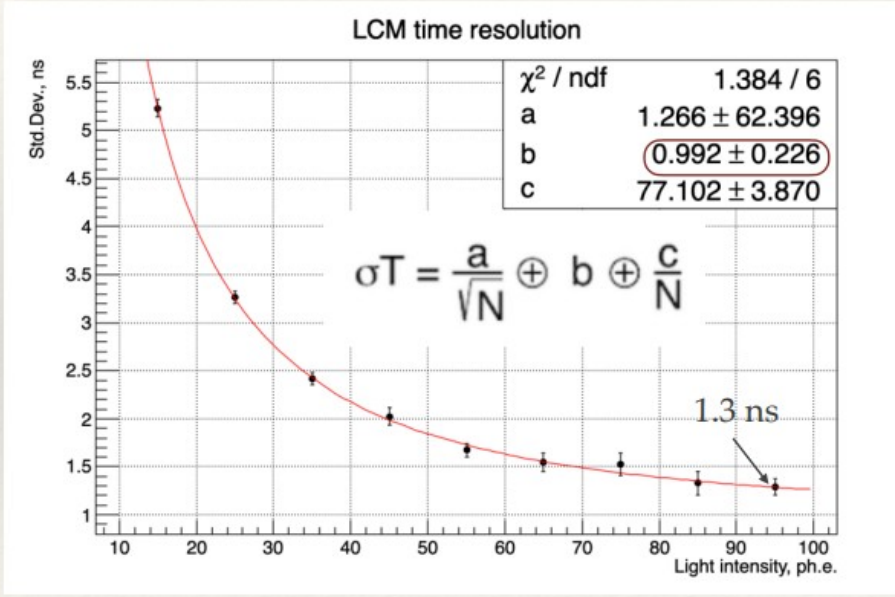


T1

TPB coating

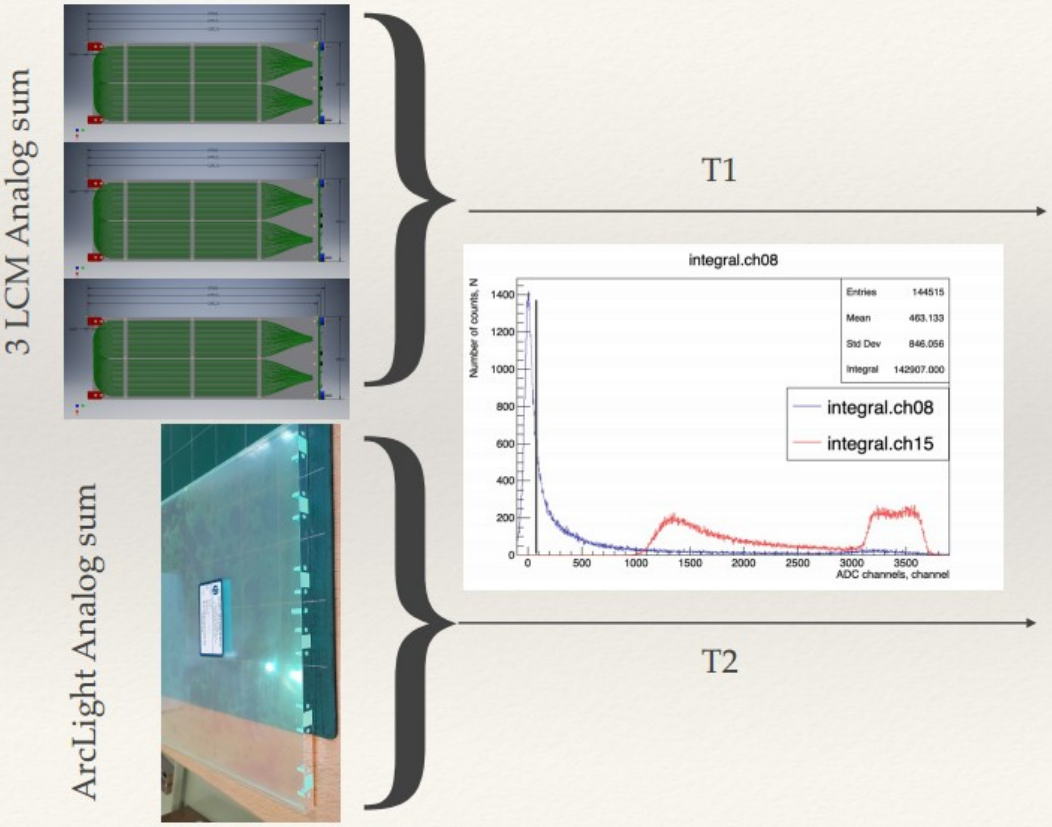


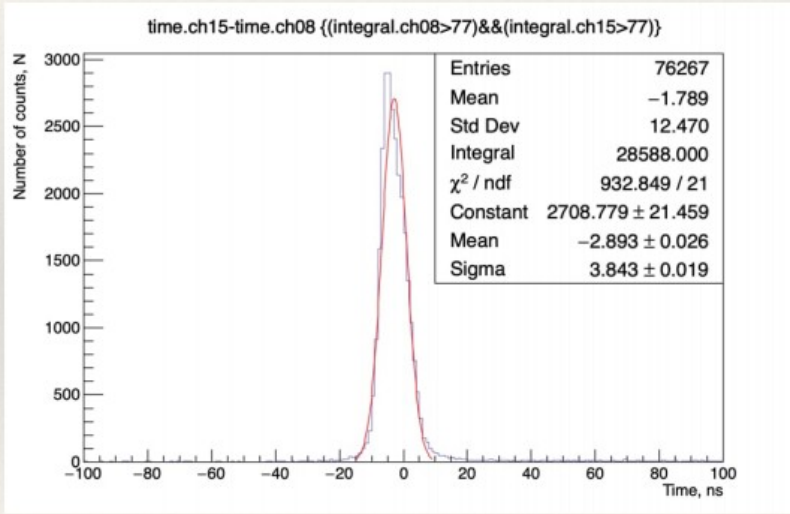
T2



SingleModule : Light detecton system

Time resolution (Threshold)

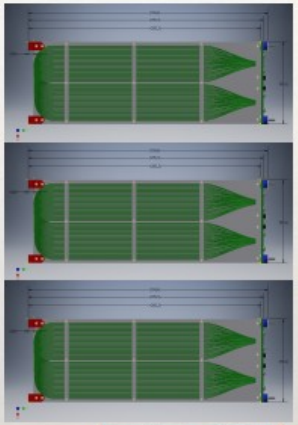




SingleModule : Light detecton system

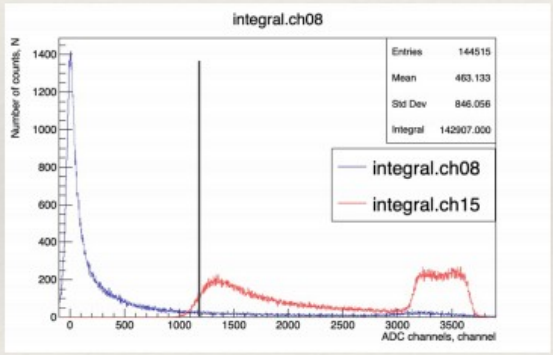
Time resolution (Threshold)

3 LCM Analog sum



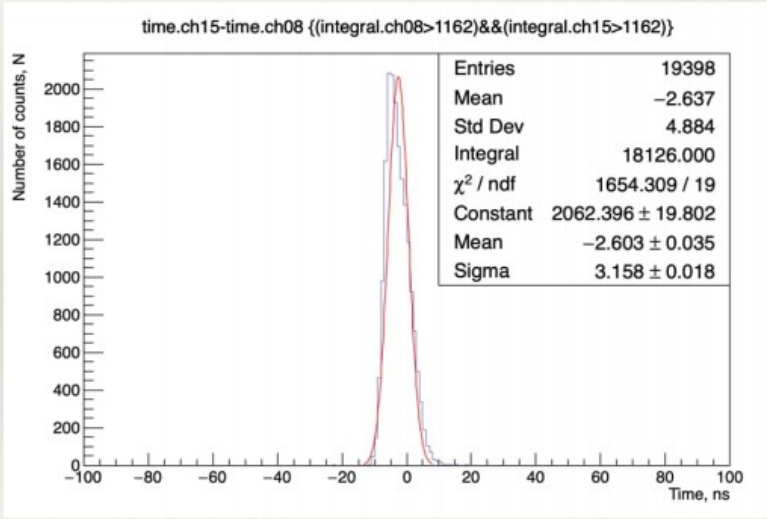
ArcLight Analog sum

T1



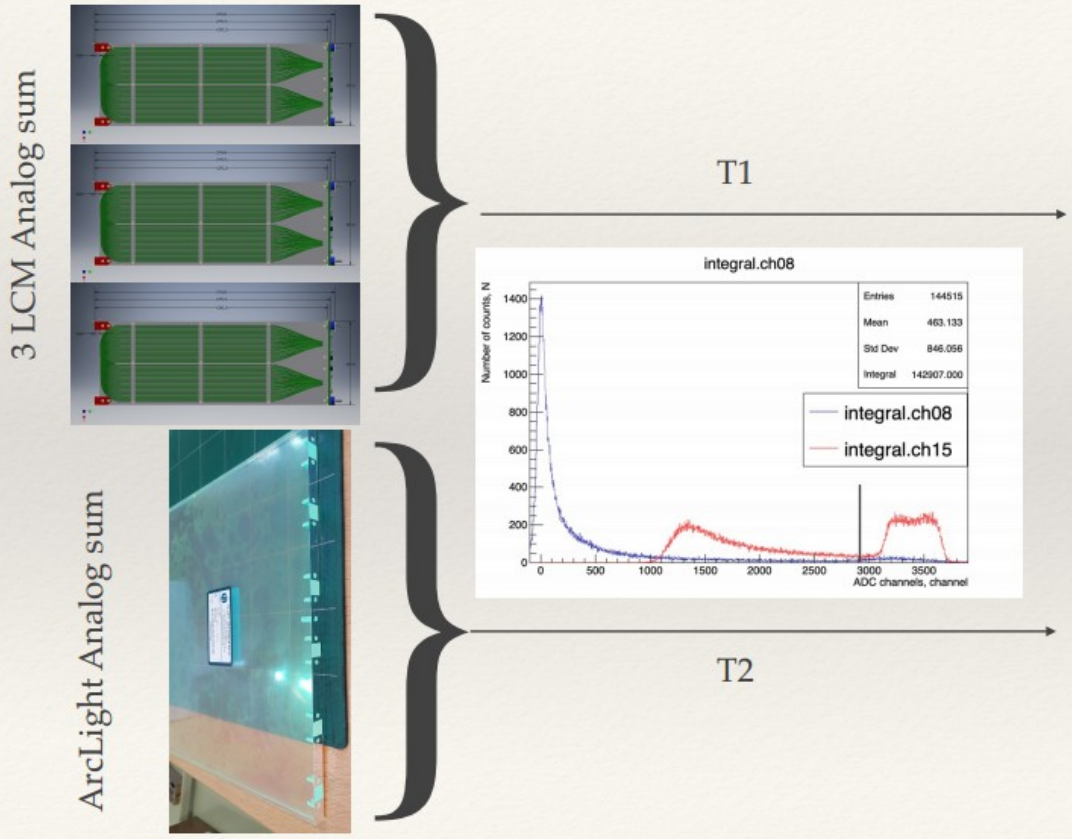
T2

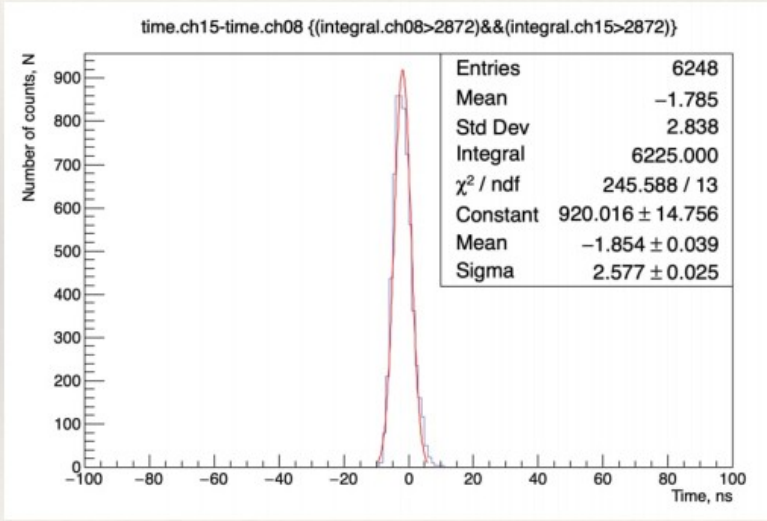
LCM trigger jitter ~ 2.3 ns [1/sqrt(2)]



SingleModule : Light detecton system

Time resolution (Threshold)

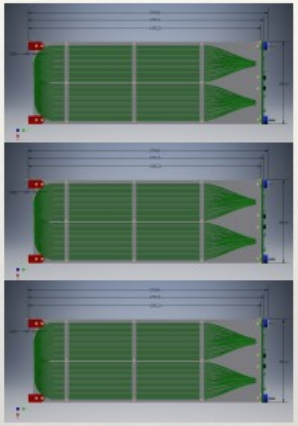




SingleModule : Light detecton system

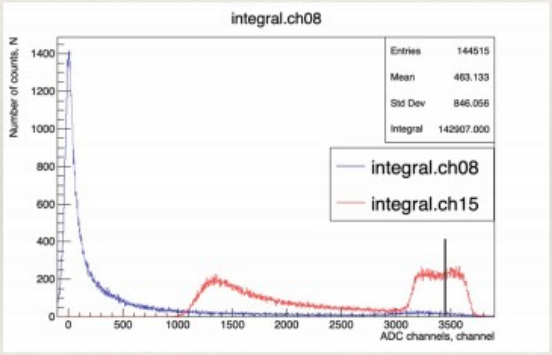
Time resolution (Max Threshold)

3 LCM Analog sum

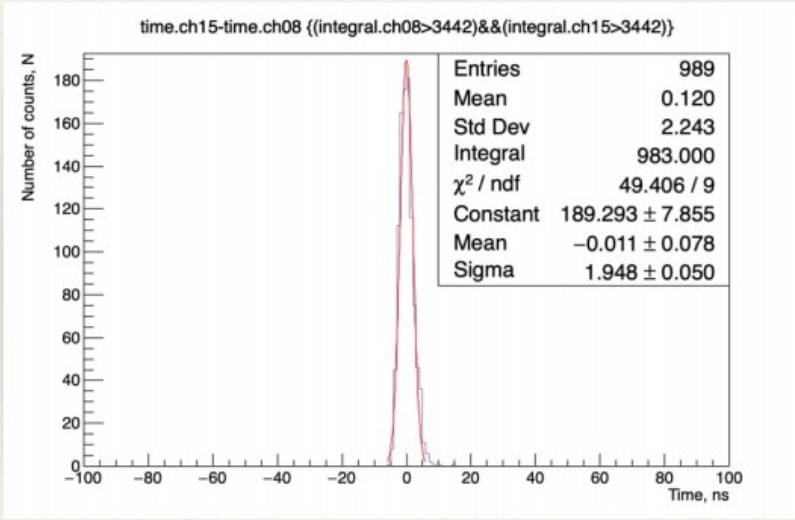


ArcLight Analog sum

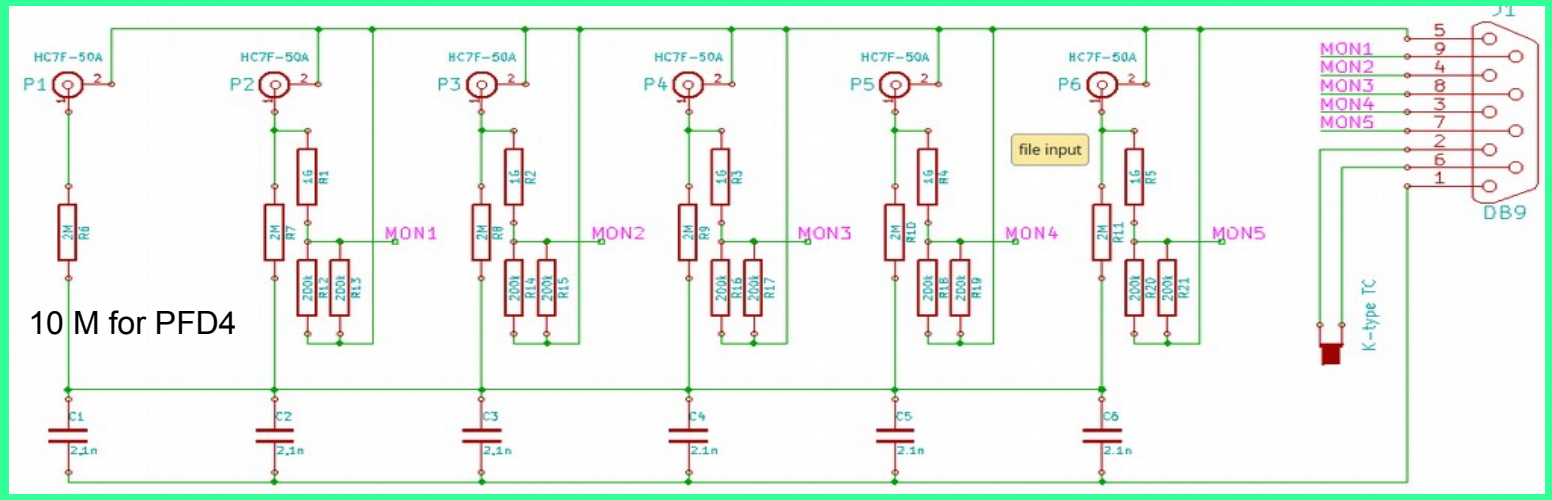
T1

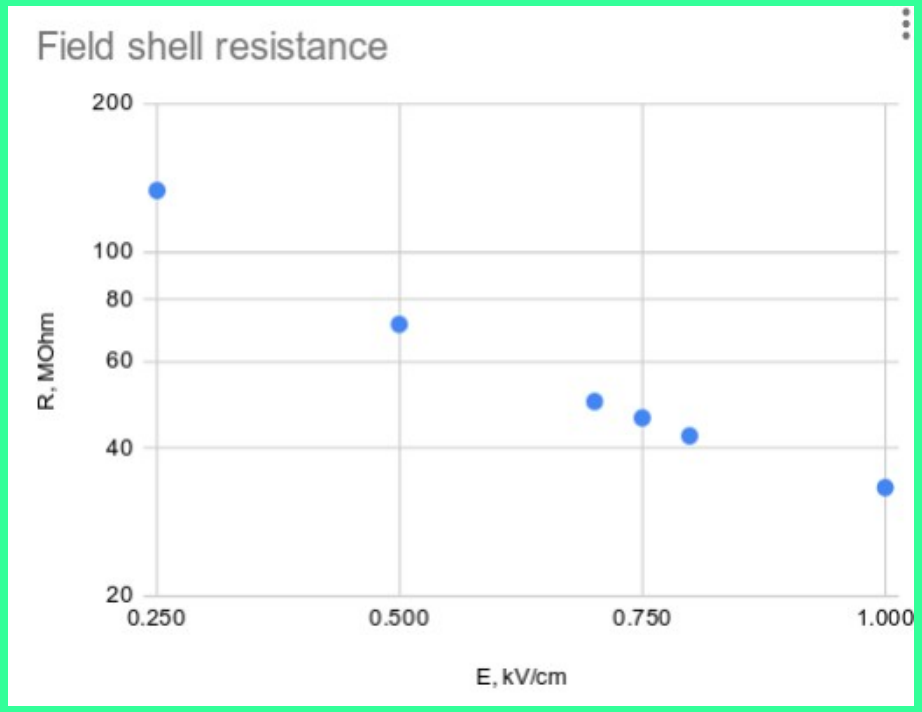


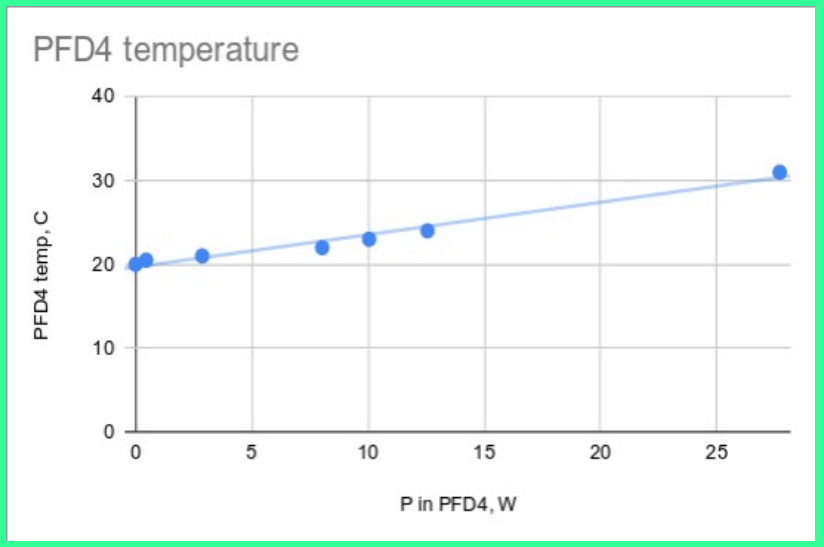
T2



SingleModule : Heat dissipation in the PFD4 HV filter







SingleModule : Heat dissipation in detector

- Effect of field shell & electronics - negligible

- Heat leak :

level loss 5mm/h -> 5.35 kg/h LAr evaporated

Power ~ 0.85 MJ/h ~ 240 W

main contribution - top flange. To be fixed.

Detector can be sealed at P=400 mbar, T=92K

In this mode filter/cooler takes full 240 W

at about 1/2 of its max capacity.

SingleCube/Module : analysis ongoing

- Accurate calibration of charge / light R/O
- Light Detection System PDE calculation (involves MC simulation)
- Charge-Light anticorrelation as a function of E-field
- Track direction by LCM timing?
- Coordinate reconstruction with ArCLight
- Triggering (event tagging) efficiency
- More