Bench test of MaPMT and frontend electronics for SoLID Cherenkov detectors

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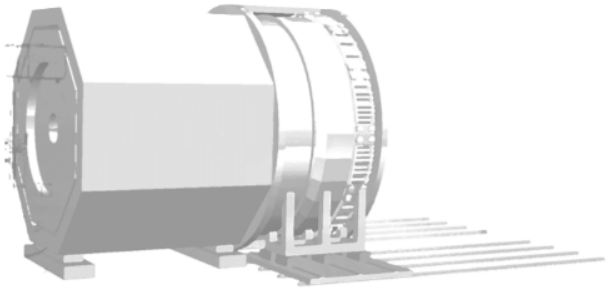


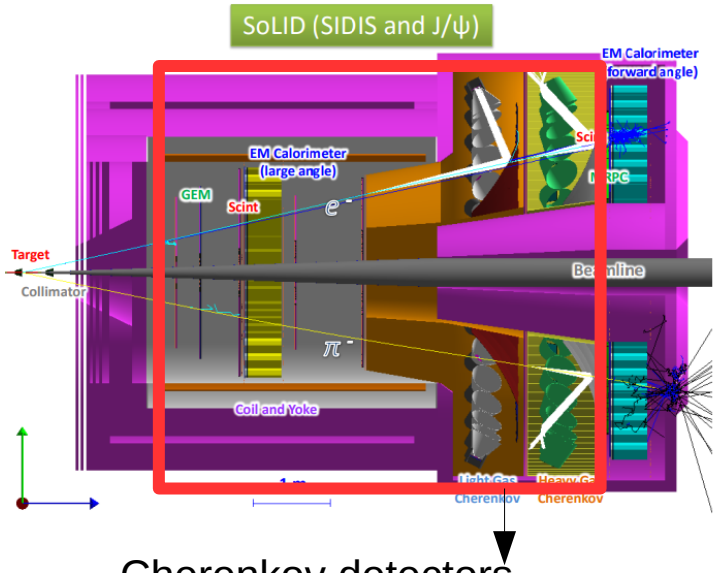
Motivation and goals

Motivation:

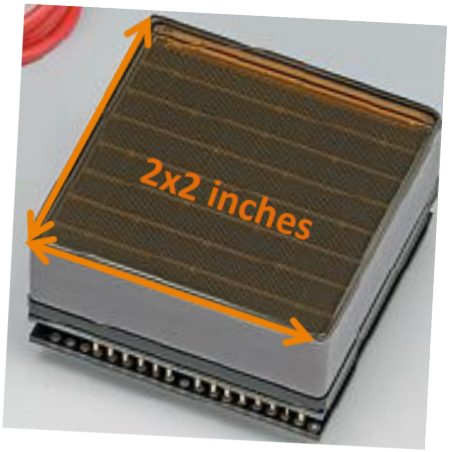
- Cherenkov detector rate as high as 200 kHz/pixel (pixel) or 4 MHz/PMT (sum)
- MaPMT with MAROC sum readout can be a potential option to handle such a high rate
- CLAS12 RICH detector validated performance only up to 2 kHz/pixel
- LED and laser was used to check the performance of MAROC readout at high rate

Goals:

- To check and confirm the expected performance of MaPMT readout at high rate
- Understand the background subtraction at high rate similar to SoLID



Cherenkov detectors



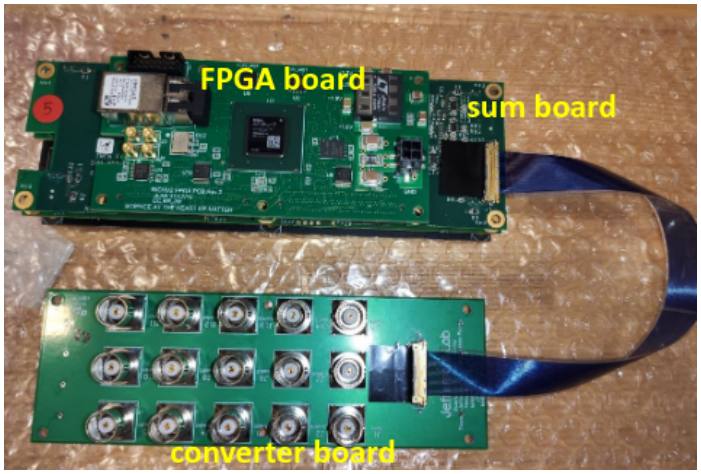
MaPMT:

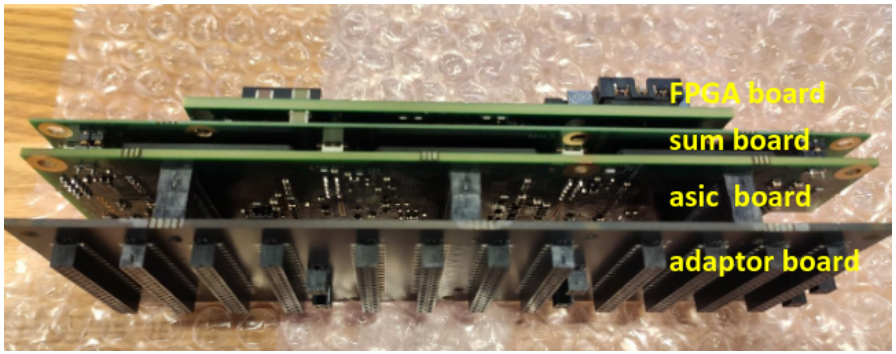
- Single photoelectron resolution
- Resistant to magnetic fields

Schematic layout (laser test)

Setting

- Used 1 H12700 MaPMT (5 x 5 cm)
  - total 64 pixels (6 x 6 mm)
- Laser and LED are used to create high rate environment
- Laser as signal and LED operating under DC voltage as background
- Triggered by clock
- **Data:**
  - CODA (FADC sum signals and TDC pixel signals)
  - TDC scaler (scaler for pixel)
  - FADC scaler (scaler for sum signal)



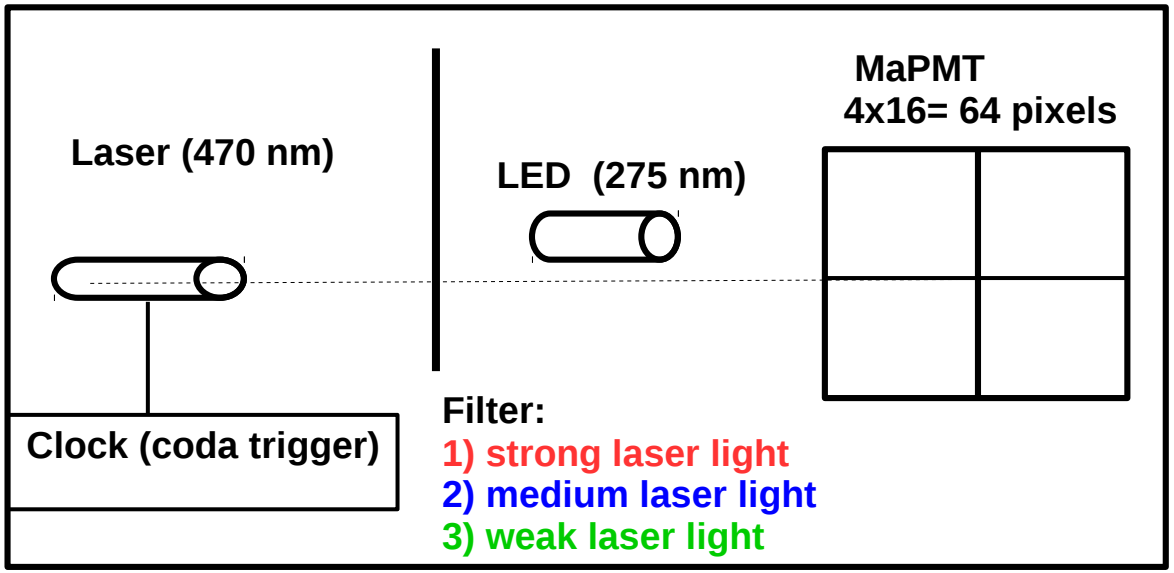


MAROC sum board

Readout by MAROC sum board

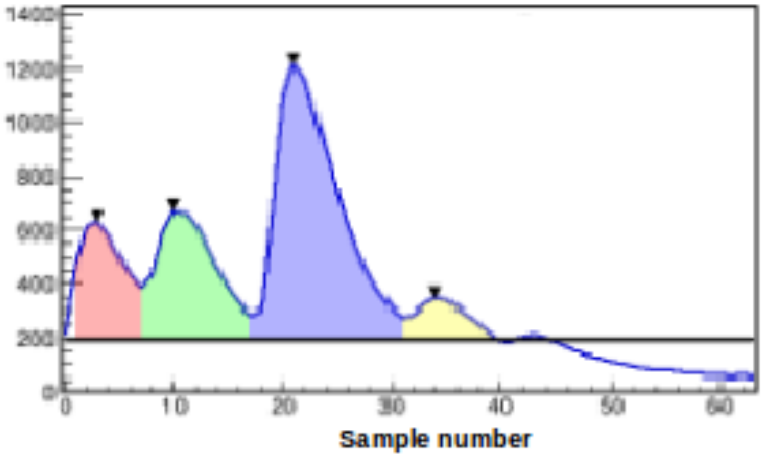
- **TDC : pixel hit information from 64 pixels**
- **FADC : sum signals (4 quads & total sum)**

Schematic layout of bench test setup

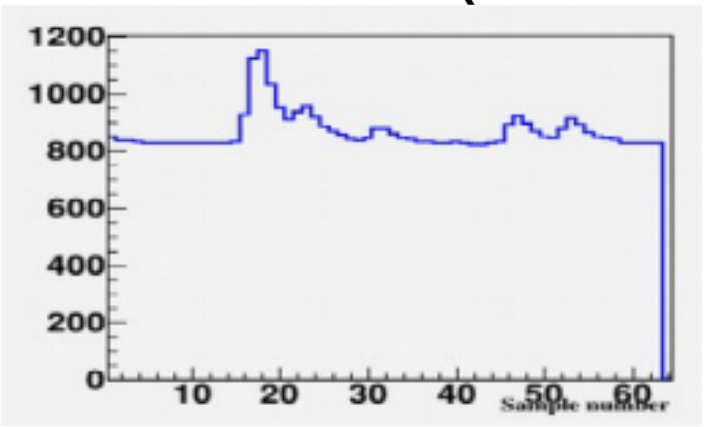


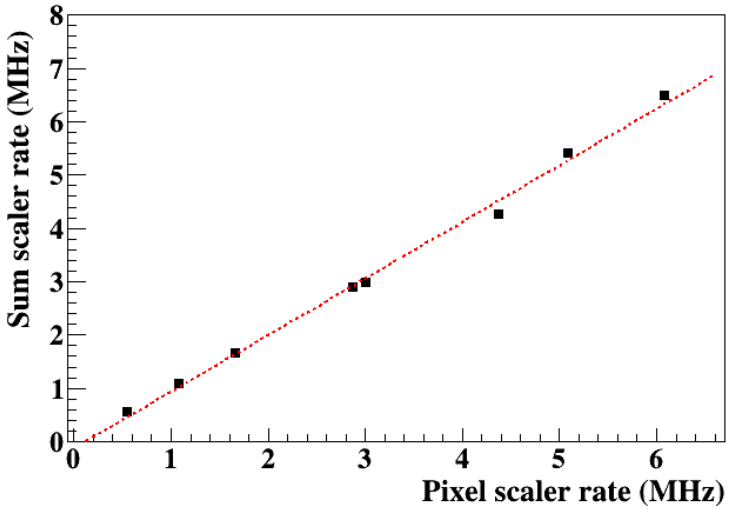
Results from laser test

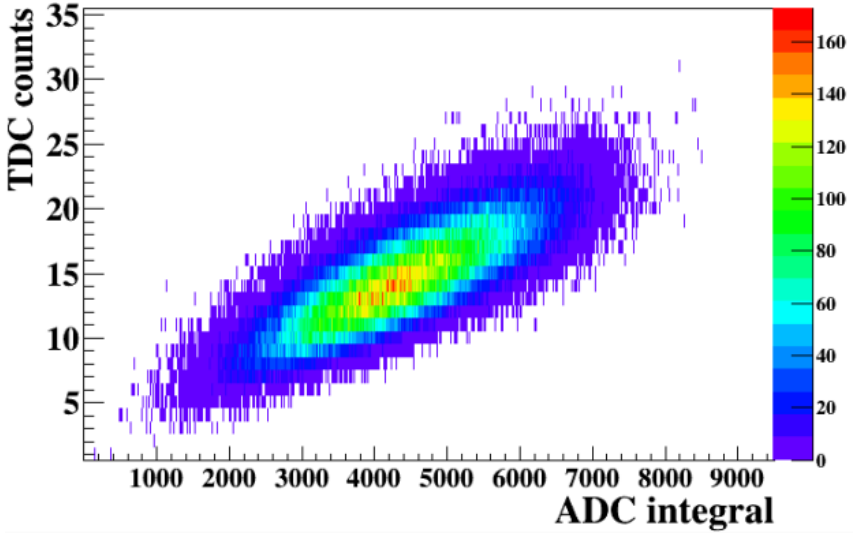
FADC waveform (Beam test)



FADC waveform (Bench test)



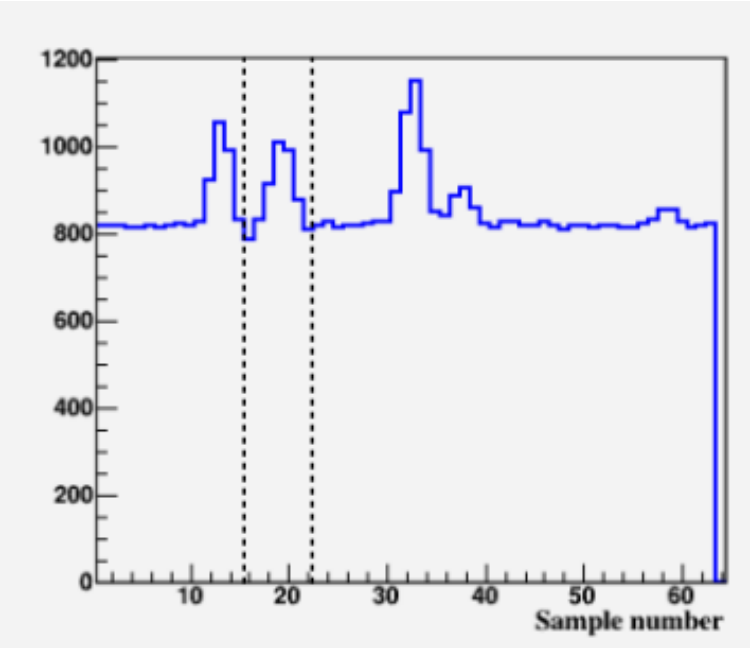


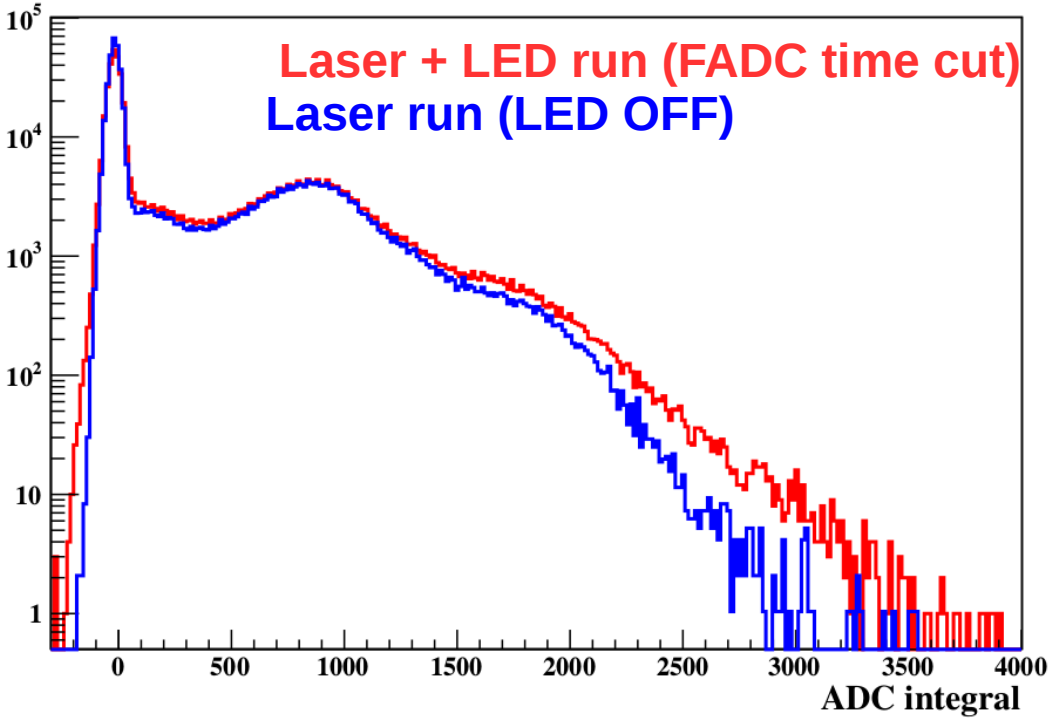


- Mimicked the beam test condition using LED and laser
- TDC and FADC scaler rates agree within 3% for rates well above than expected in SoLID
- Linear correlation between pixel and sum signal readout, summing electronics works well

Background subtraction

FADC Waveform

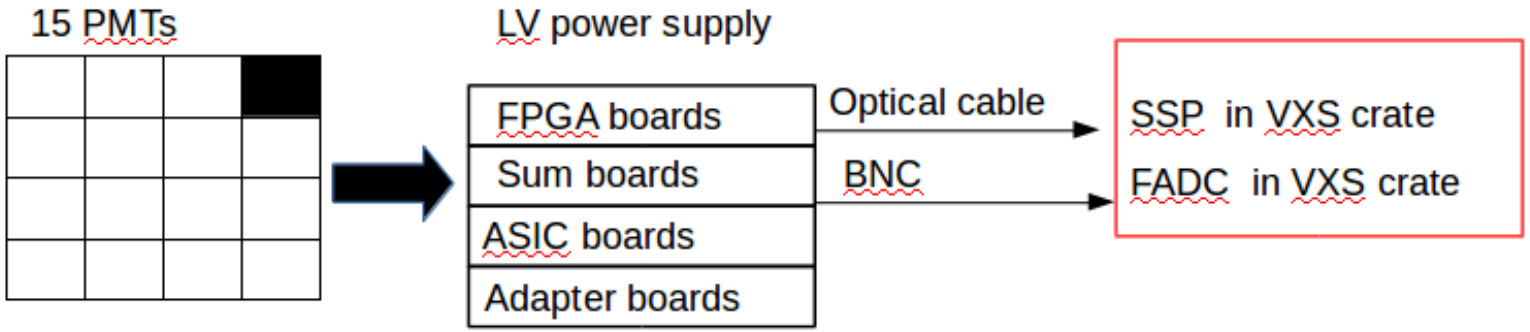




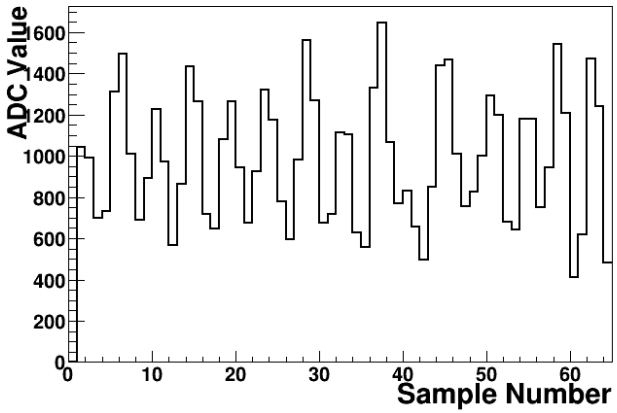
- Laser + LED run => extract signal applying FADC timing cut => compare FADC spectrum with laser run (LED Off)
- Based on the FADC timing information, background can be subtracted fairly well up to the rate expected in SoLID (4MHz/PMT)
- Spatial information along with timing cut further helps to discriminate the background
- Will utilize the spatial information from Cherenkov ring (cosmic muon on lucite) to discriminate background

FADC signal oscillation

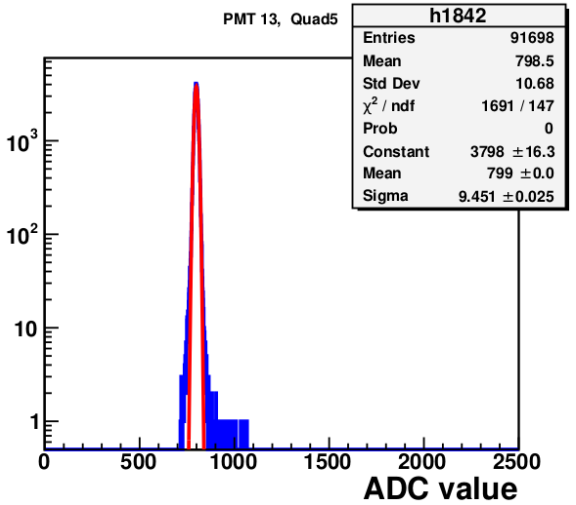
Thanks to Benjamin Raydo



MAROC sum electronics



Pedestal width after modification of sum board



- FADC signal oscillates when all 5 board are powered
- Origin of oscillation from sum board mainly coupling of low voltage

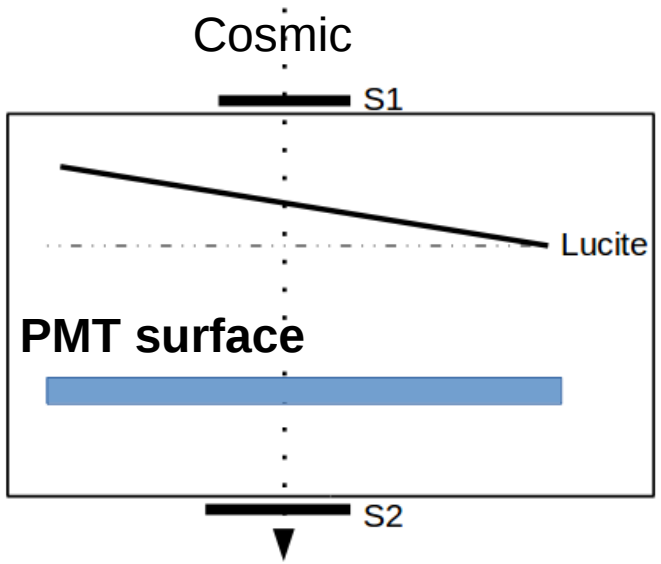
Solution

- Separate the LV connector to FPGA and sum board
- Add voltage regulator on sum board

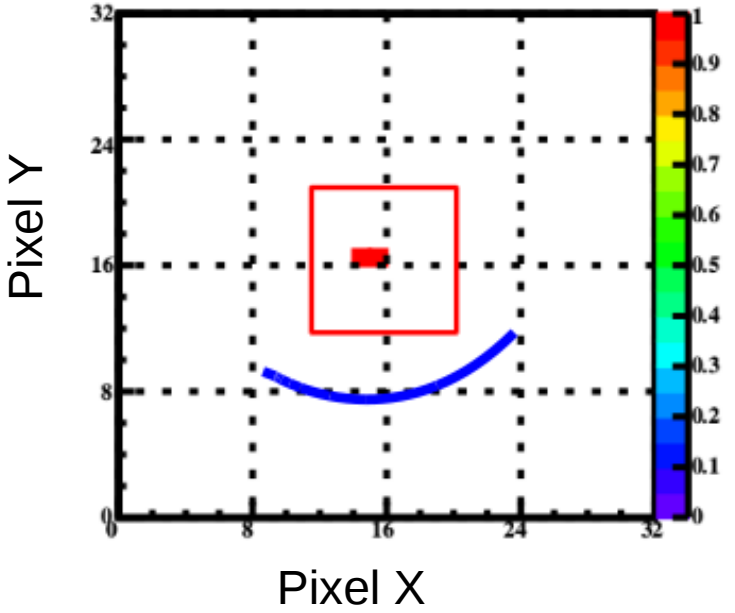
Result

- Pedestal width reduced by factor of 5
- Pedestal are comparable with the width with 1 PMT, 1 board

Schematic layout (Cosmic test)



15 MaPMTs arrays (15 x 64 pixels)



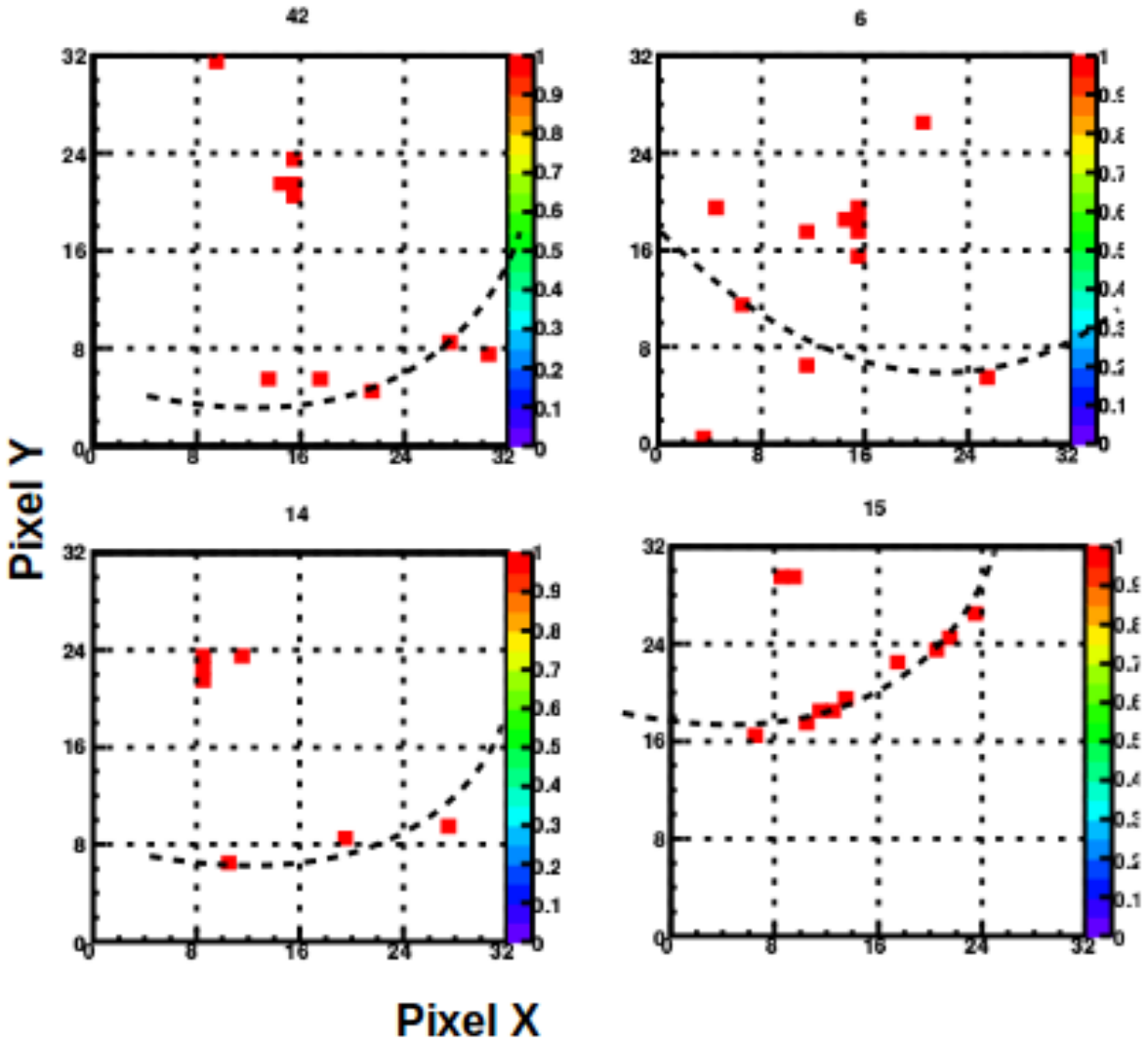
- Radiator lucite (n = 1.5)
- Cherenkov opening angle (θ_{cone}) = 48.2^o
- Critical angle for total internal reflection (θ_C) = 41.8^o
- Partial ring due to total internal reflection
- Lucite is inclined so that Cherenkov ring from vertical muon can be observed

- Trigger formed by two scintillators (S1 and S2) in coincidence
- Background with LED operating at DC Voltage

Goal

- Study background subtraction using spatial and time information

Cherenkov ring



Cosmic data (LED off)

- Limited number of photo-electron as we have thin lucite (1cm)
- Will take data will thick lucite (4x) and with LED as background

Conclusion

- MaPMT with MAROC sum readout was tested on the bench using LED and laser
- With laser and LED, the rates similar to the SoLID running condition was achieved
- MaPMT with MAROC readout can perform well up to the rate expected in the SoLID (Linear correlation between the TDC and FADC signal)
- Spatial information along with time information from Cherenkov ring can be used to improve the background subtraction

Next ..

- Will take cosmic data in presence of background from LED to study background elimination

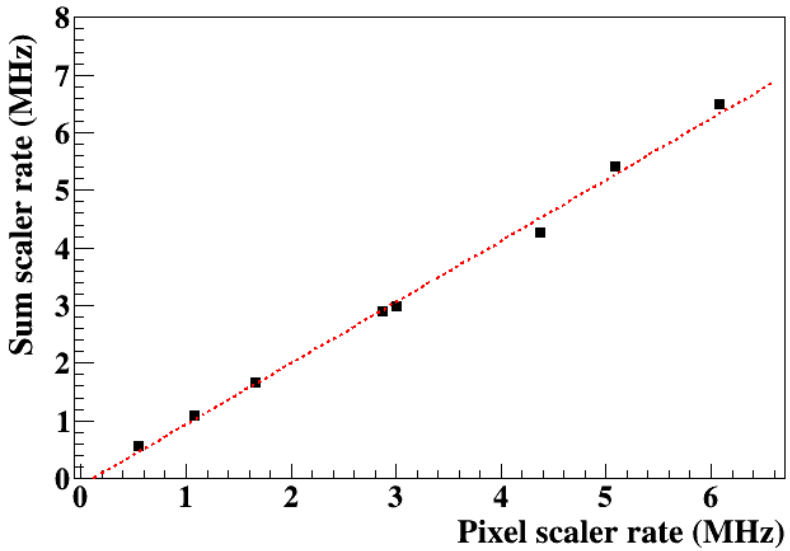
Acknowledgement: The SoLID collaboration
Especially Zhiwen Zhao, Benjamin Raydo, Andrew Smith, Alexandre Camsonne, Stephen Wood, Marco Contalbringo, Jack McKission, Roberto Malaguti, Jeff Wilson, and Haiyan Gao

Research subcontract No. 0F-60069 (Argonne National Lab)

Back up

Pixel scaler rate/Sum scaler rate

Rate (kHz)	LED off			LED 2.09 V		
Laser off				45		
Laser 10	0.2	0.7	2	45	45	47
Laser 100	5	4	21	45	48	65
Laser 200	7	8	42	45	52	86
Laser 500	15	20	106	46	62	150
Laser 1000	28	42	220	48	80	266



Laser filter:

- **Strong laser light**
- **medium laser light**
- **weak laser light**

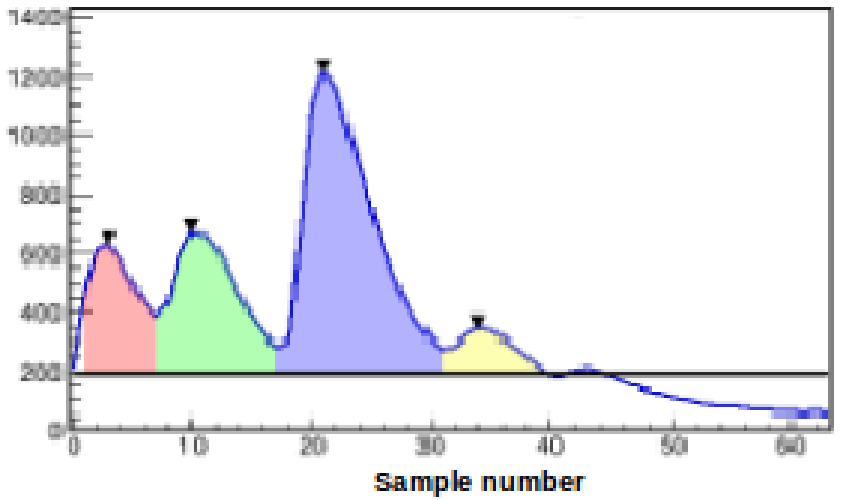
$$\text{Sum scaler rate} = \frac{\text{Average pixel scaler rate} \times 64}{\text{Average pixel ocuupancy}}$$

- In TDC, single event may result in many hits but FADC sums as a single event
- Average pixel occupancy is average number of pixel hits per event
- Pulsed laser and LED operating at DC voltage can provide the desired pixel and PMT sum rates
- Up to the rates expected in SoLID the TDC scaler and FADC scaler rates agrees within 3%

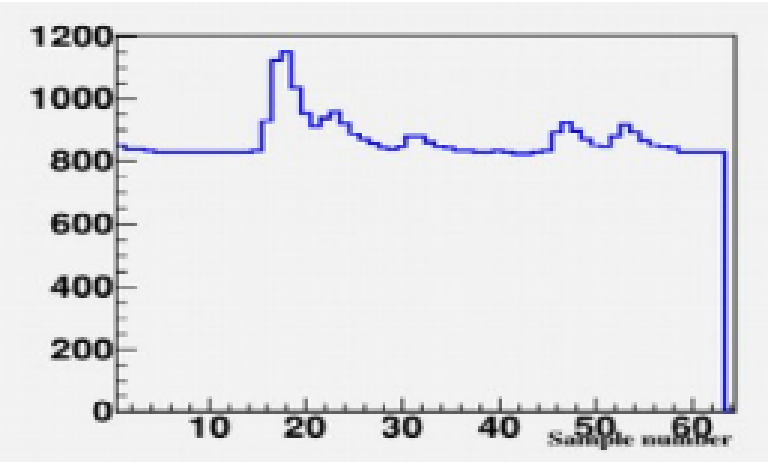
FADC sum signal

- LED and Laser can mimic the beam test background

FADC waveform (Beam test)



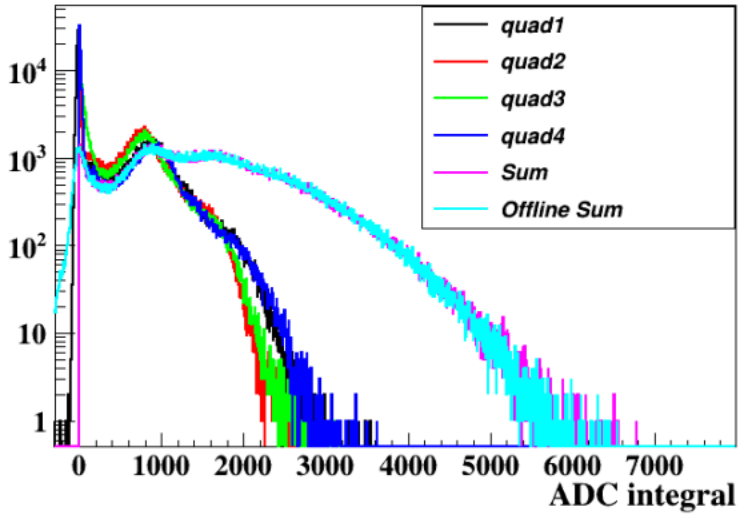
FADC waveform (Bench test)



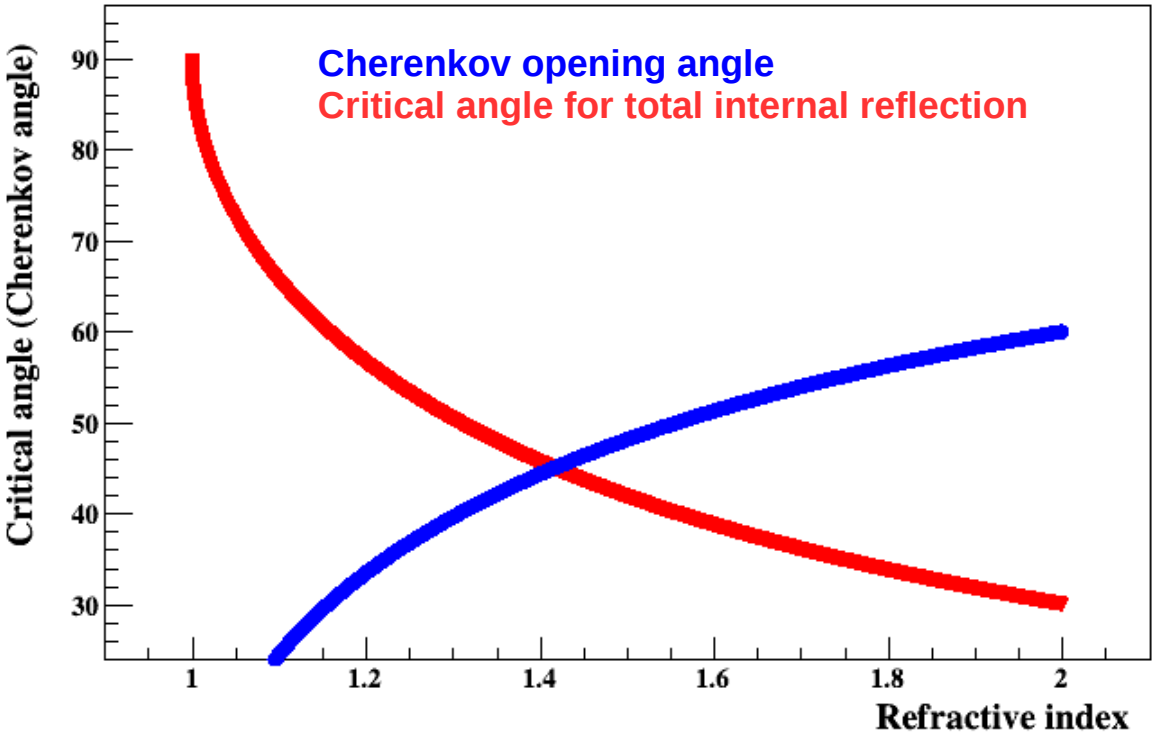
- FADC sum signal (5 channels):
  - 4 quad sums (each quad sum 16 pixels)
  - Total sum (sum all 64 pixels)

- FADC sum signal performing well up to the rate expected in SoLID

Offline sum= Quad1 + Quad2 + Quad3 + Quad4



Total internal reflection



- To observe the full ring material with refractive index less than 1.4 is needed
- However, the solid material with refractive less than 1.4 is not available

$$\theta_c = Sin^{-1}\left(\frac{1}{\mu}\right) = 41.8^\circ$$

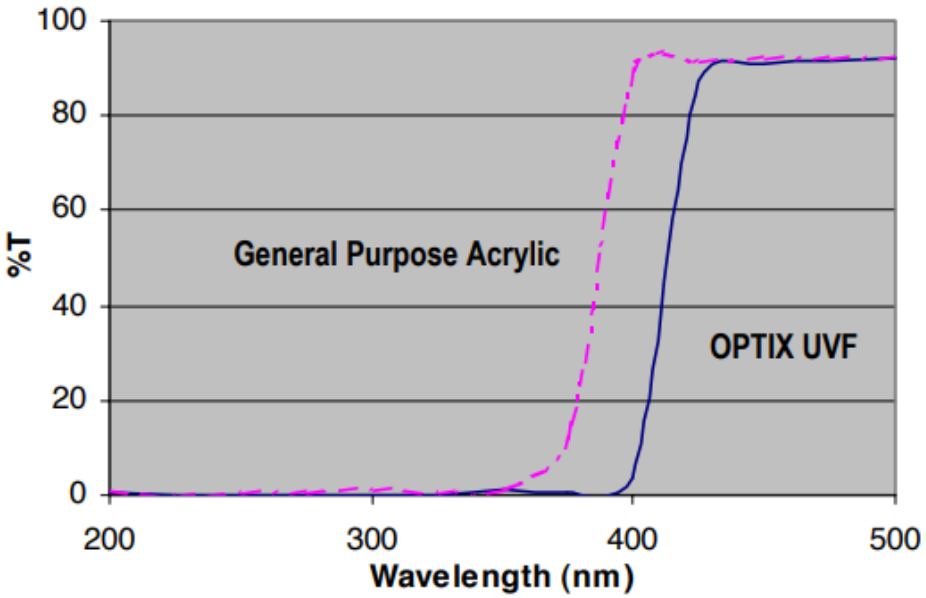
where θ_c is critical angle above which light gets internally reflected.

$$\theta_{cone} = Cos^{-1}\left(\frac{1}{\mu}\right) = 48.2^\circ$$

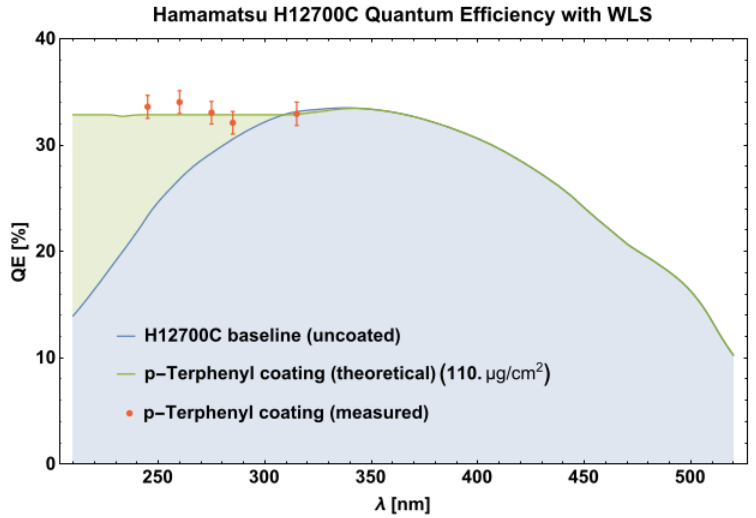
where θ_{cone} is opening angle of the Cherenkov light.

Transmittance of Cherenkov light through lucite

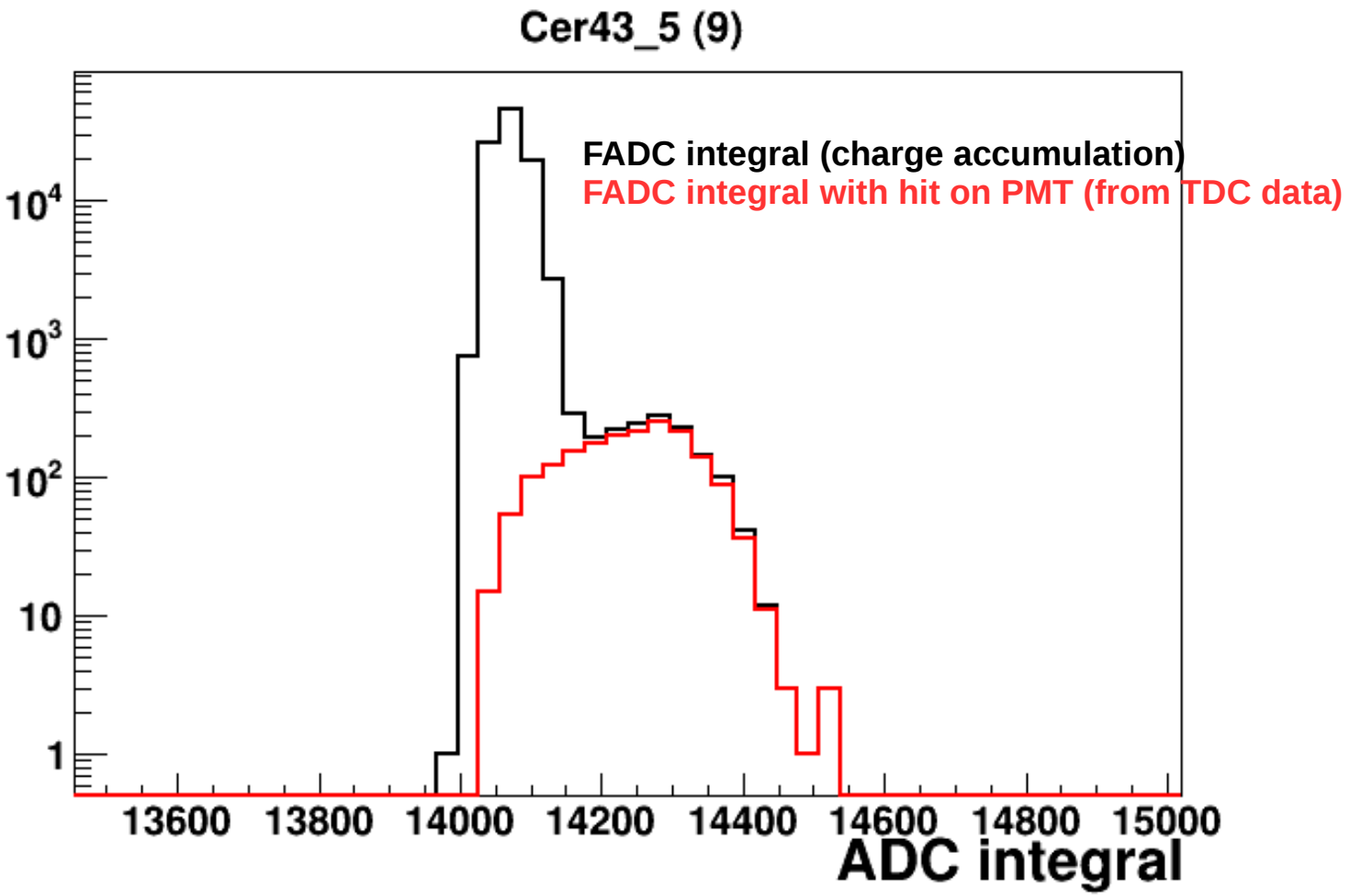
https://www.acplasticsinc.com/media/documents/PD_OptixUVF.pdf



	No. photo-electron (N)
Total (t=1.0 cm lucite) (200 nm - 600 nm)	850
Transmittance [400-600]nm	210
QE (0.1)	21
Total internal reflection	5
Transmittance (0.85)	4



Single photo-electron detection



- Pulsed LED, LED at minimum voltage to detect SPE
- For simplicity, data taken with one pixel enabled
- MAROC TDC data sensitive to SPE