Studies with the LArIAT Light Collection System

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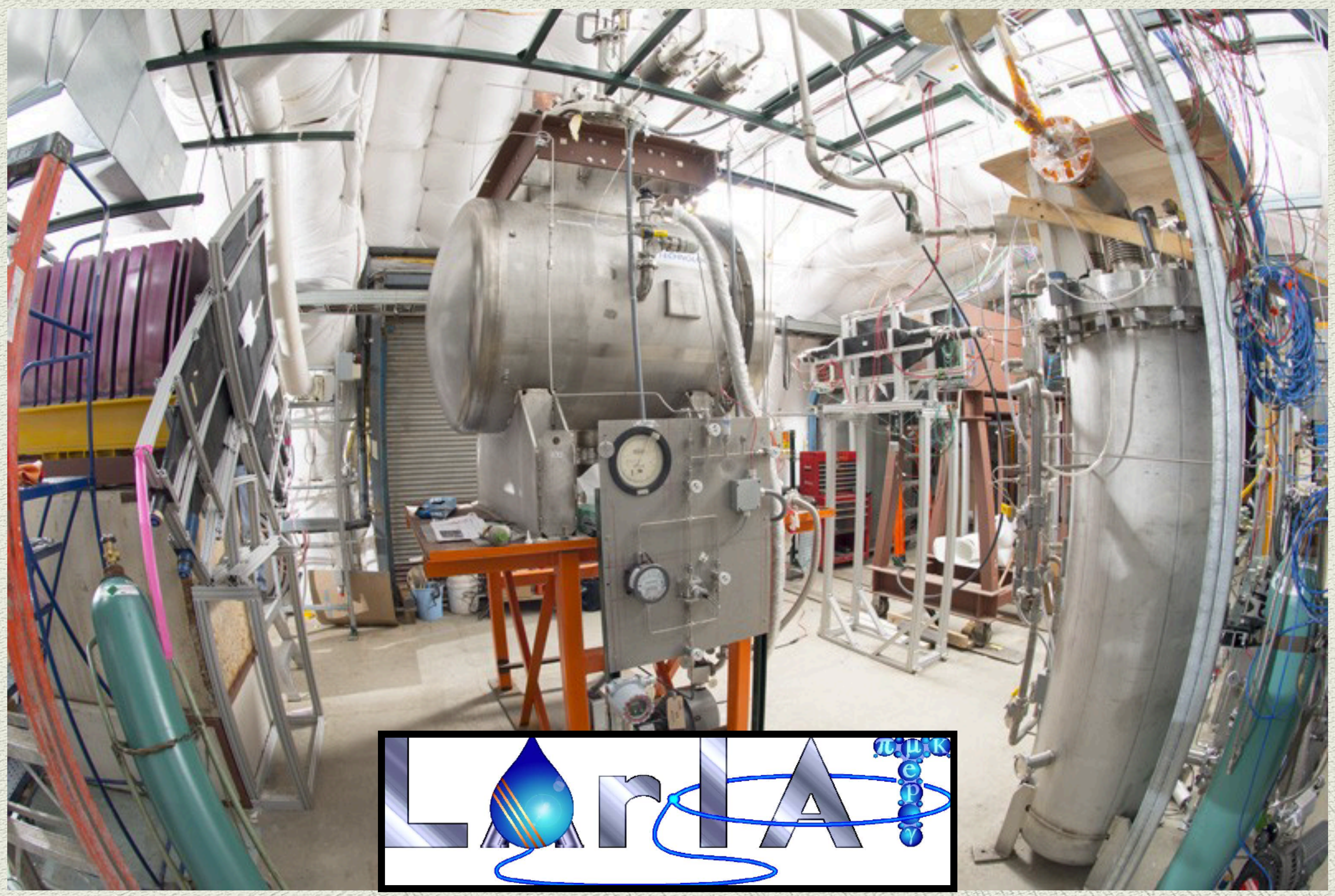
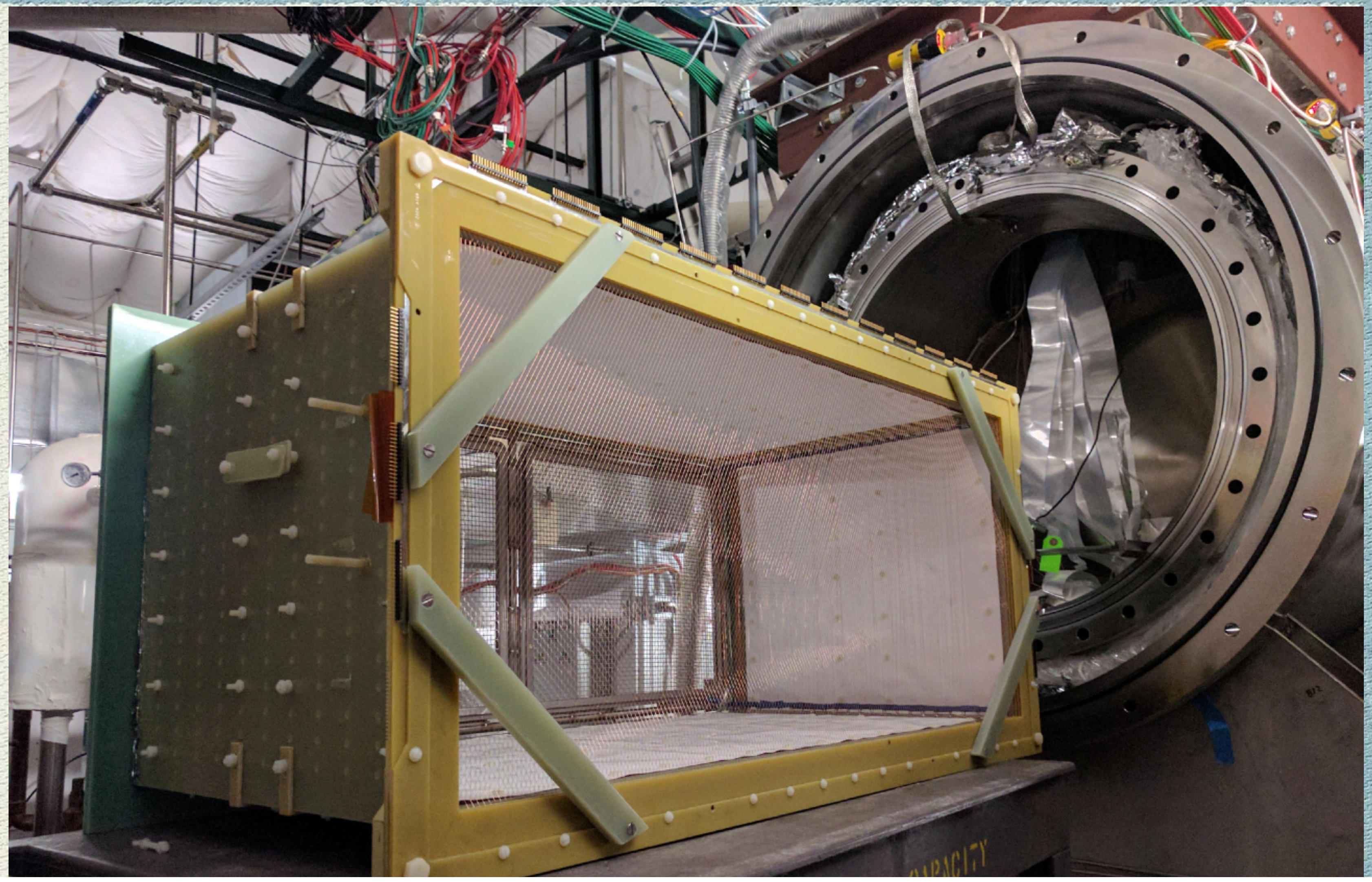
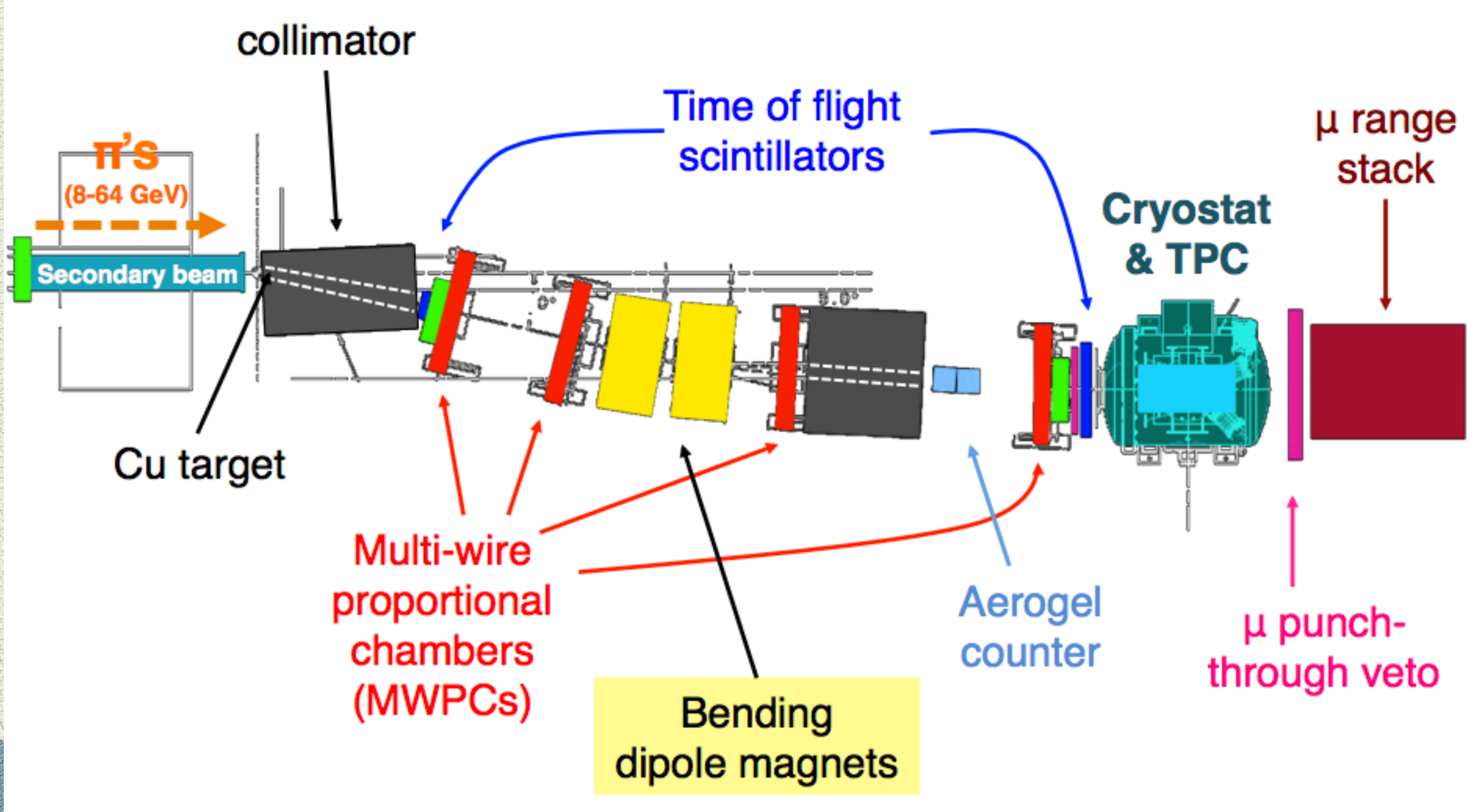
on behalf of the LArIAT Collaboration



Liquid Argon TPC In A Testbeam

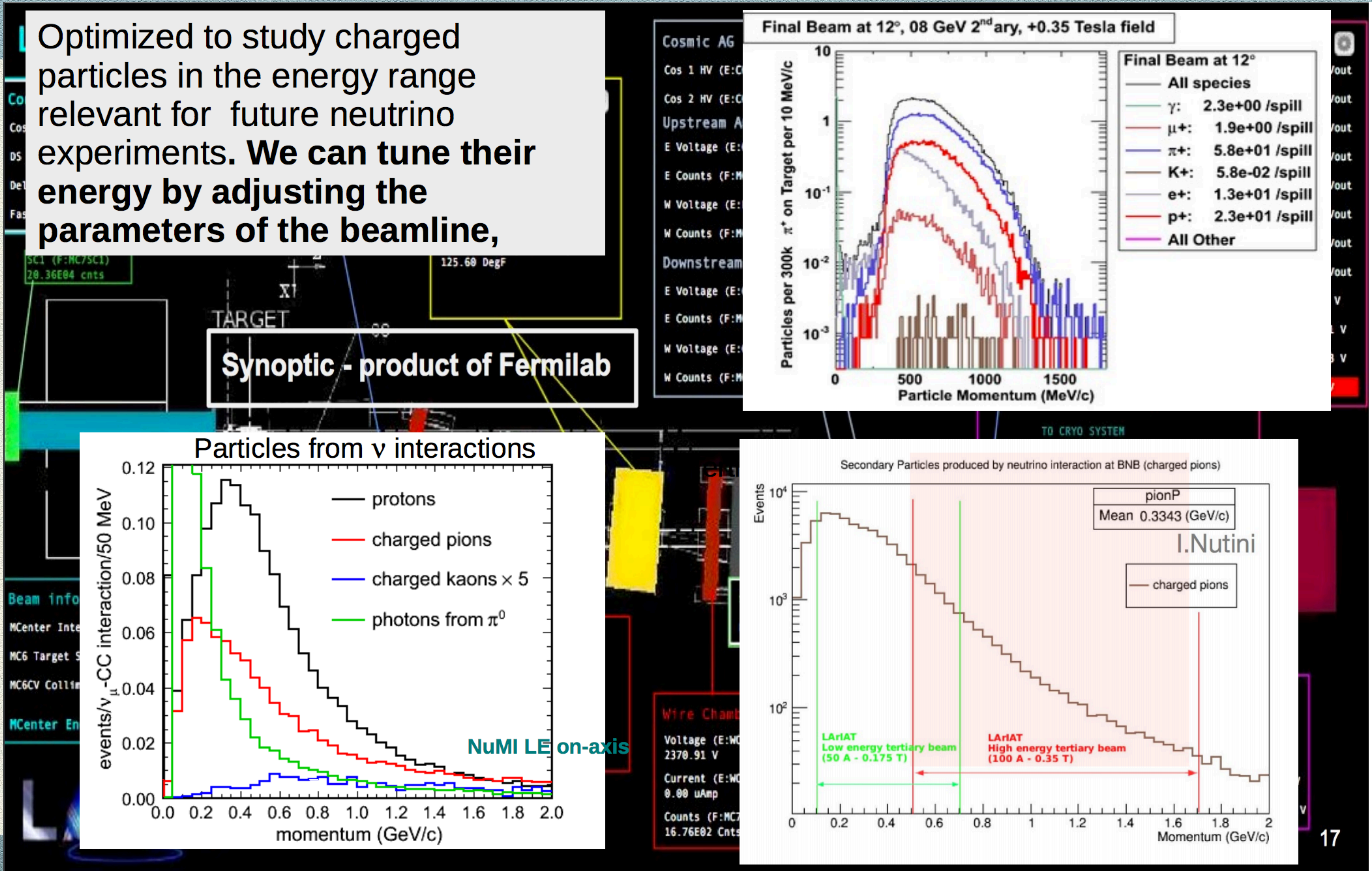
- Is a 0.25 ton liquid argon TPC in a charged particle beam;
- Calibration and characterization of the calorimetric response of LAr TPCs;
- Lives in the FTBF, exposed to a tertiary beam.





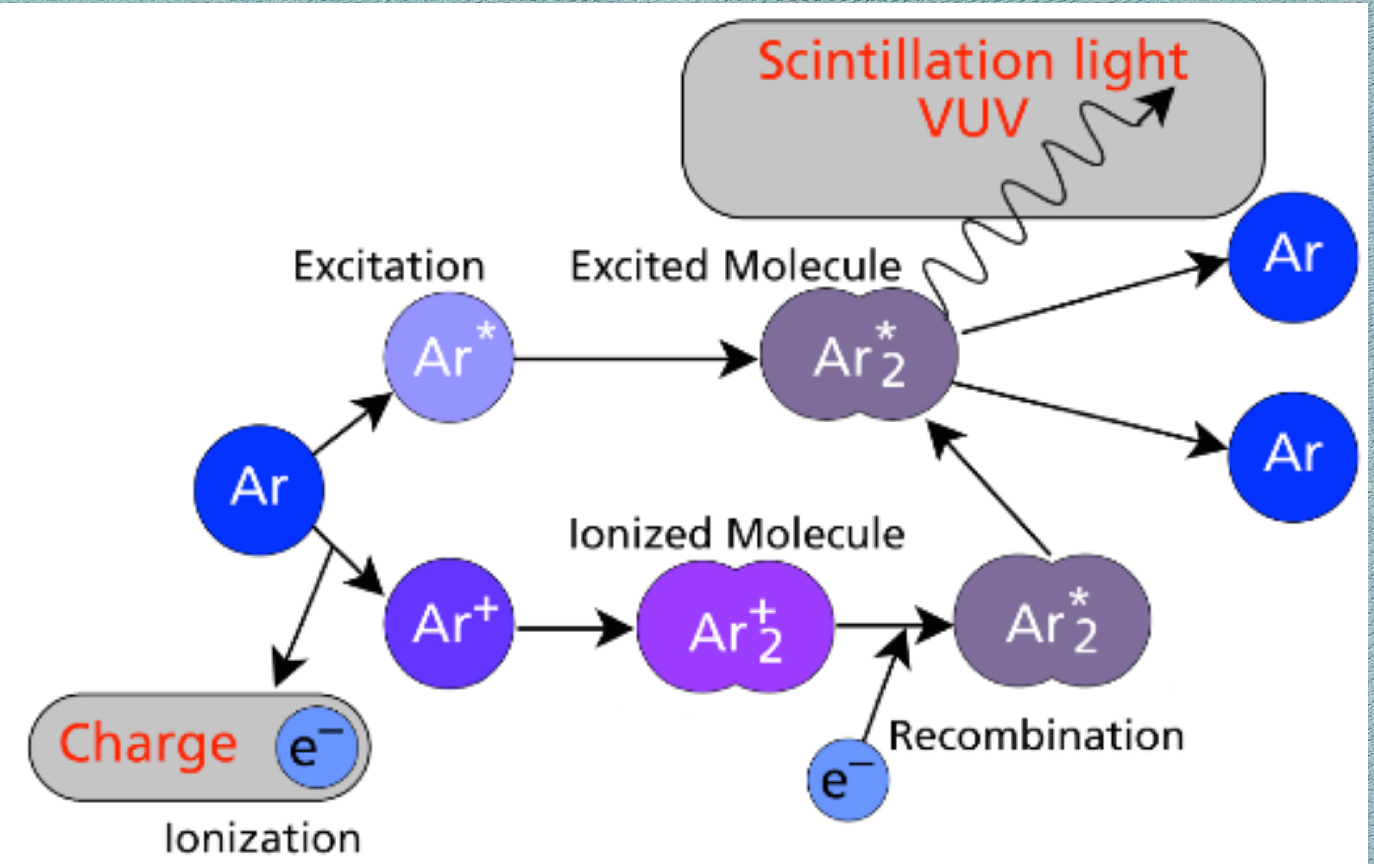
LArIAT: beam features

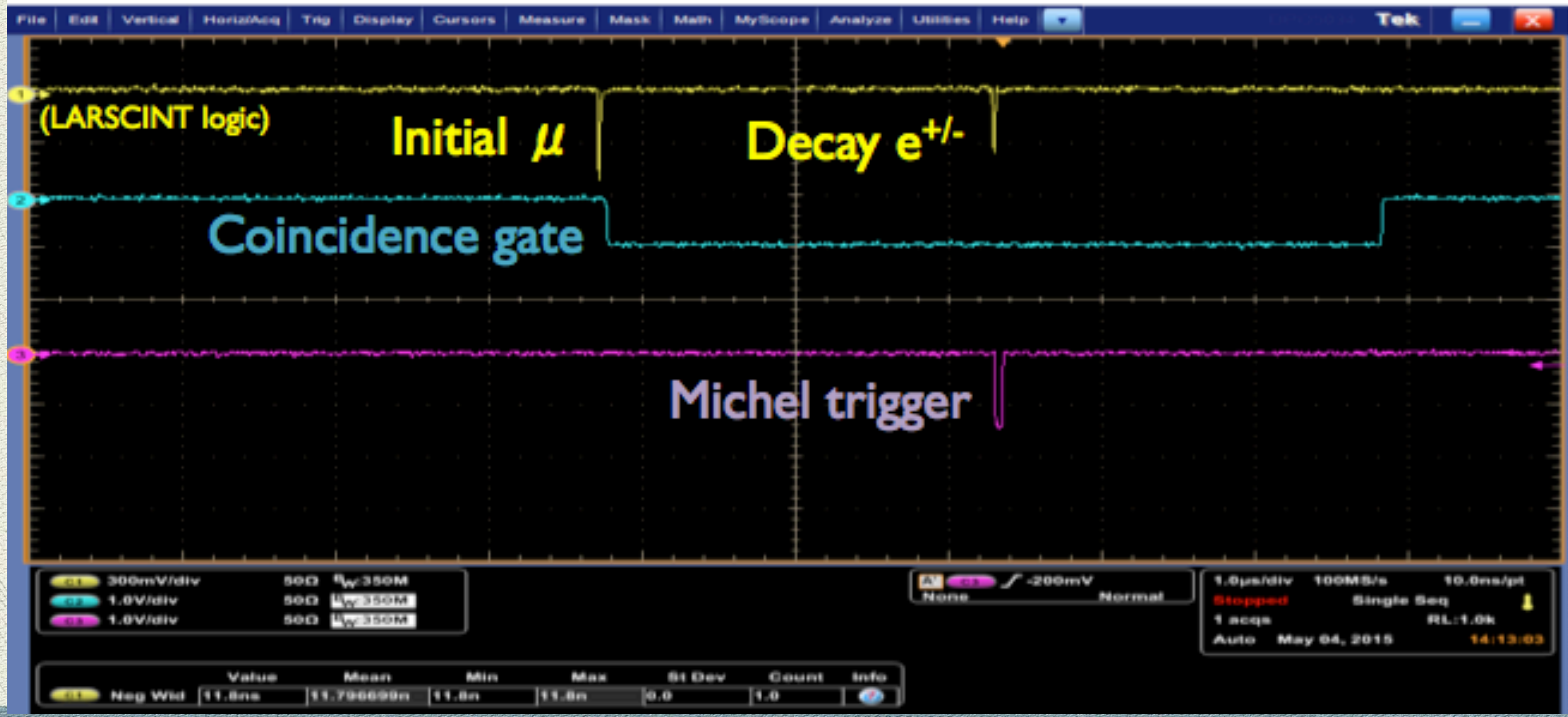
Optimized to study charged particles in the energy range relevant for future neutrino experiments. **We can tune their energy by adjusting the parameters of the beamline,**



LArTPCs - Charge and Light

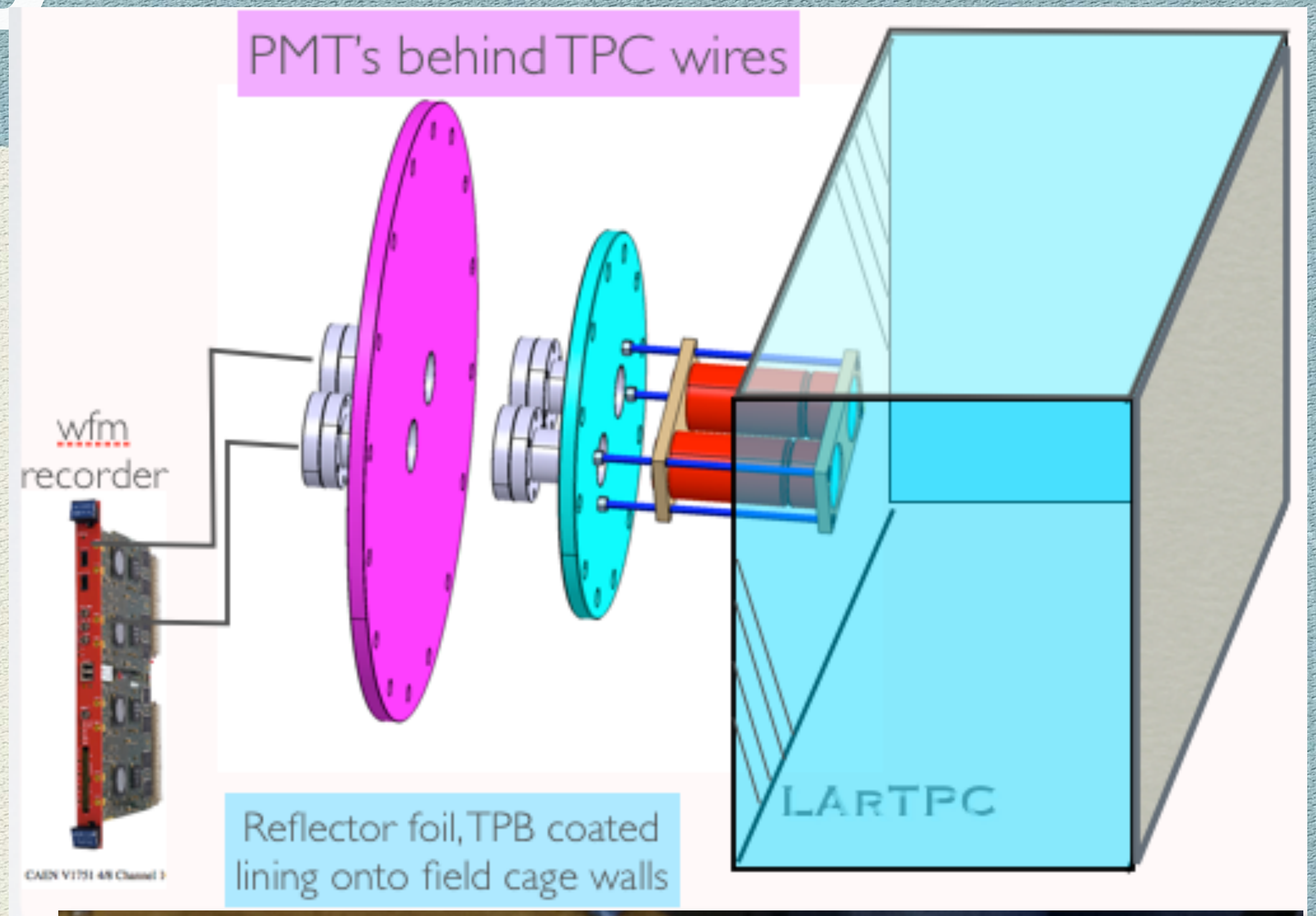
- LArTPCs collect electrons from ionization -> for 3D reconstruction
- And scintillation light (128nm) for:
  - Trigger
  - Michel electrons identification
  - Potentially: PID, calorimetry.

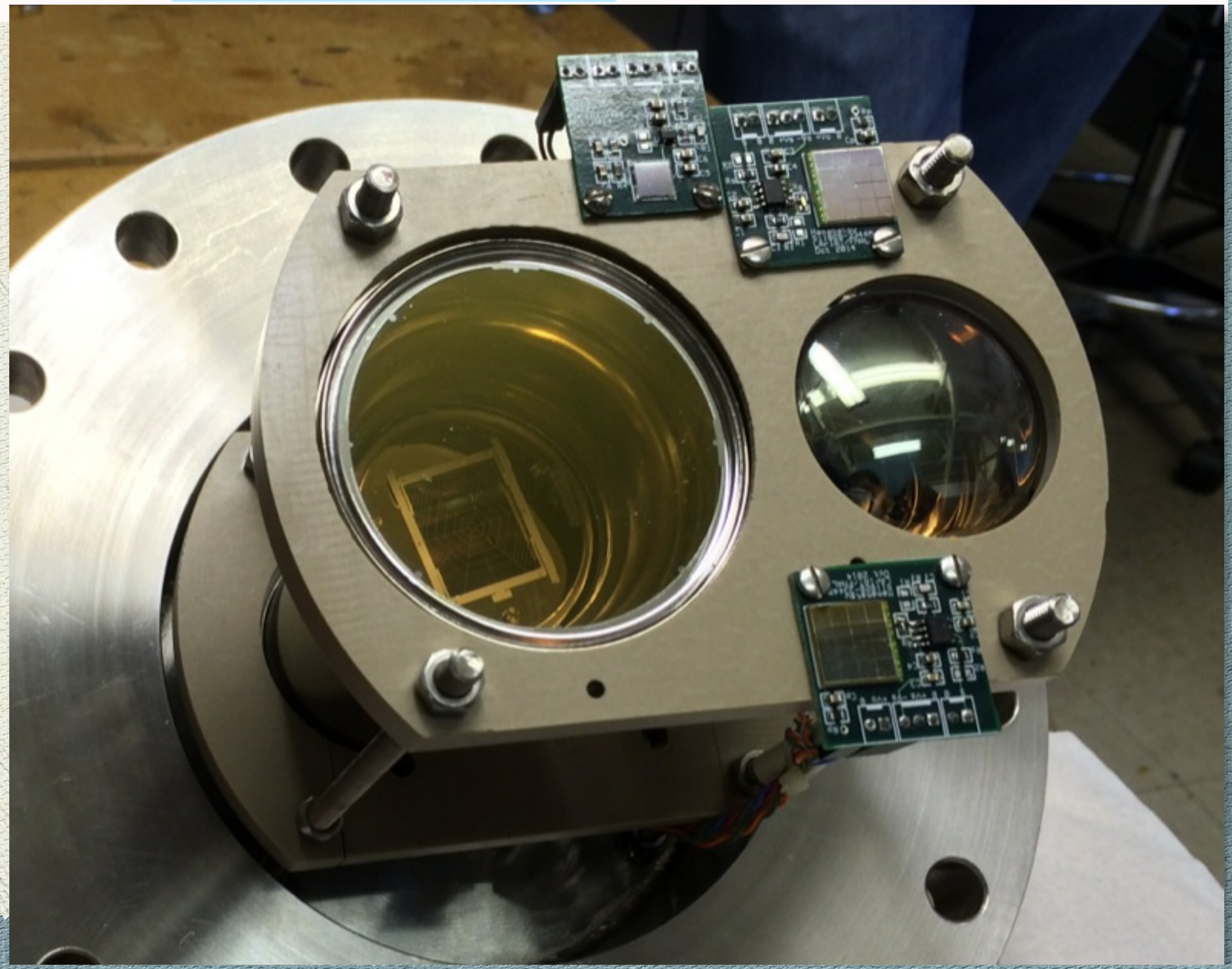




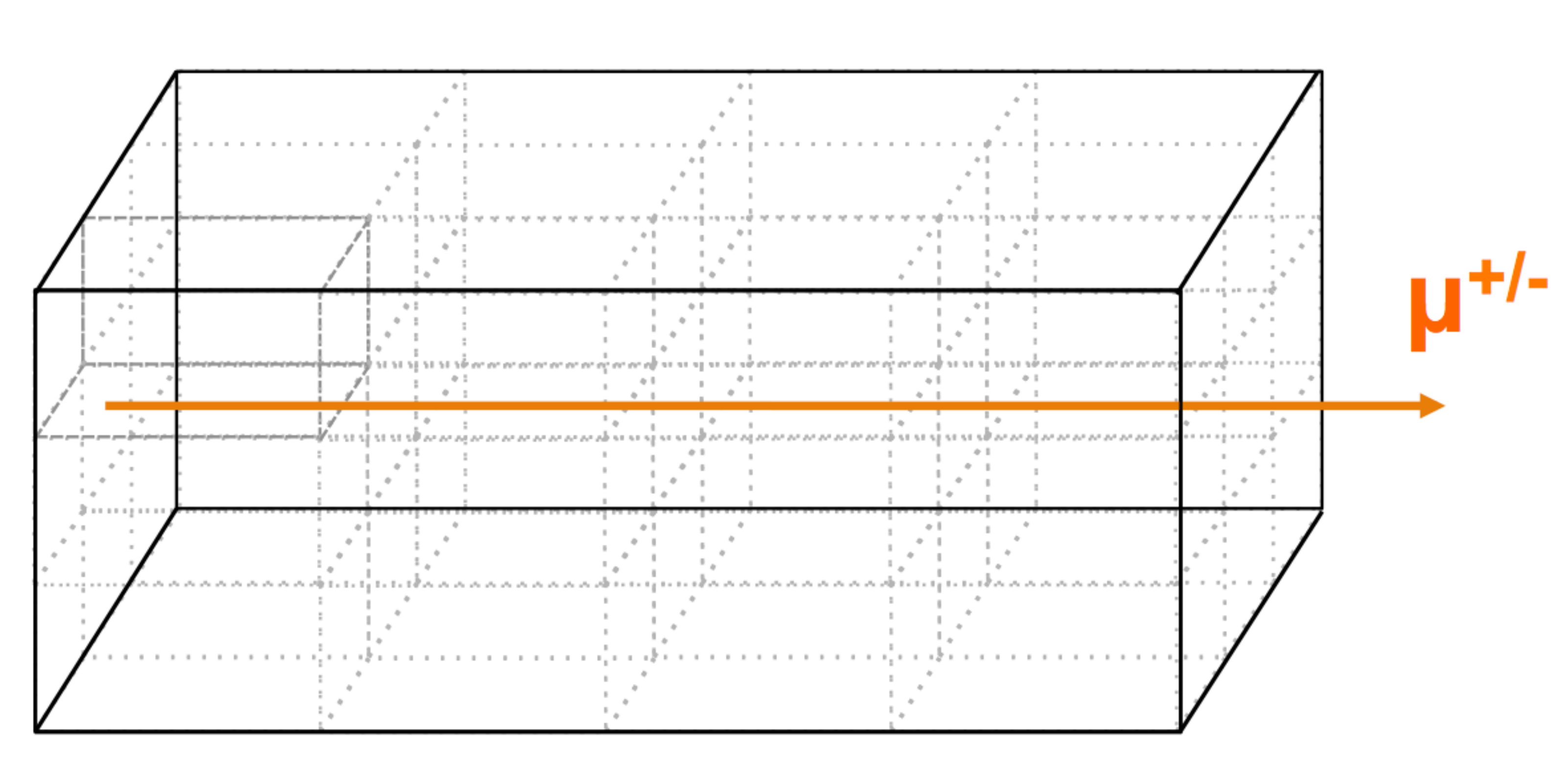
LArIAT Light Collection System

- Is placed behind the wire planes;
- TPC is lined with TPB coated reflective foils;
- On the first 2 runs was composed by:
  - 1 - 2” ETL PMT;
  - 1 - 3” Hamamatsu PMT;
  - 3 - SiPMS

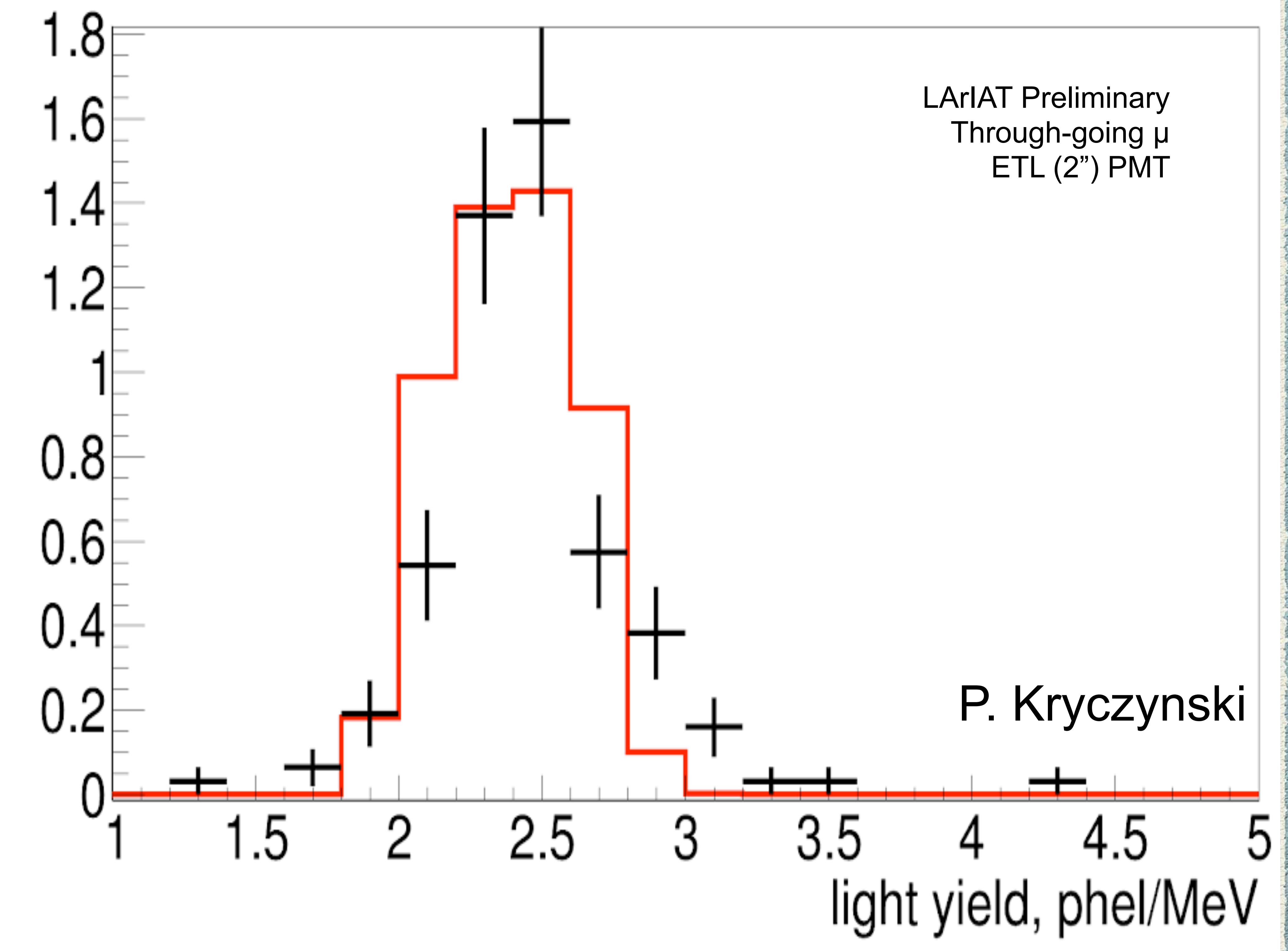




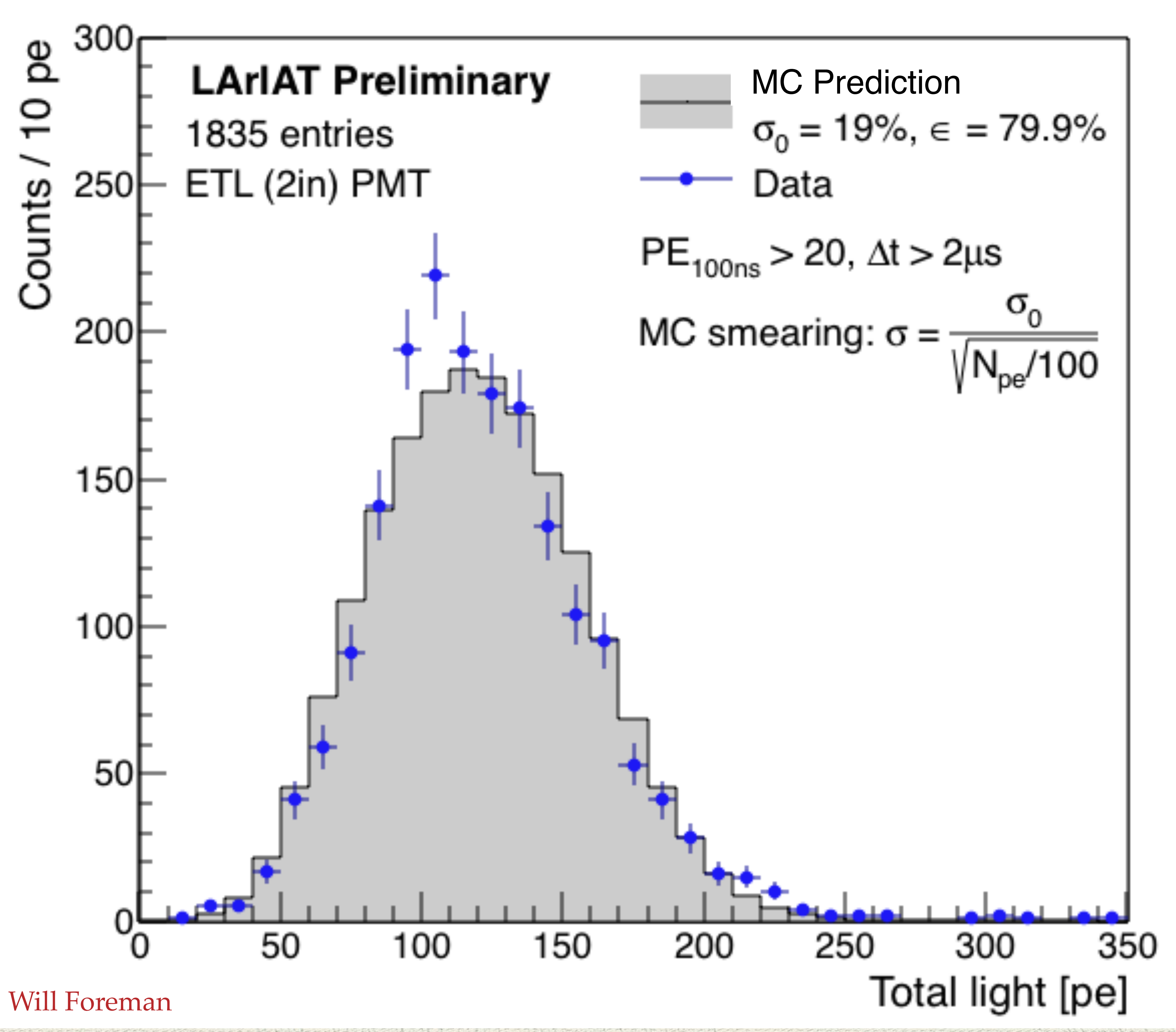
Validating the simulation



- Simplest topology - easy to understand
- Great to test predictions vs reality
- Data agrees with MC predictions
- More details on Szelc's talk



Michel Electrons - photoelectron spectrum



- Michel Electron candidates signals integrated to get PE spectrum
- Data in approximate agreement with preliminary MC
  - Gives confidence in MC predicted LY: 2.4 pe/MeV for 2” ETL PMT (Run1)
- More details on Szelc’s talk

Physics with Michel

μ⁻ have a predicted 75% capture rate on argon nuclei (no Michel electron present).

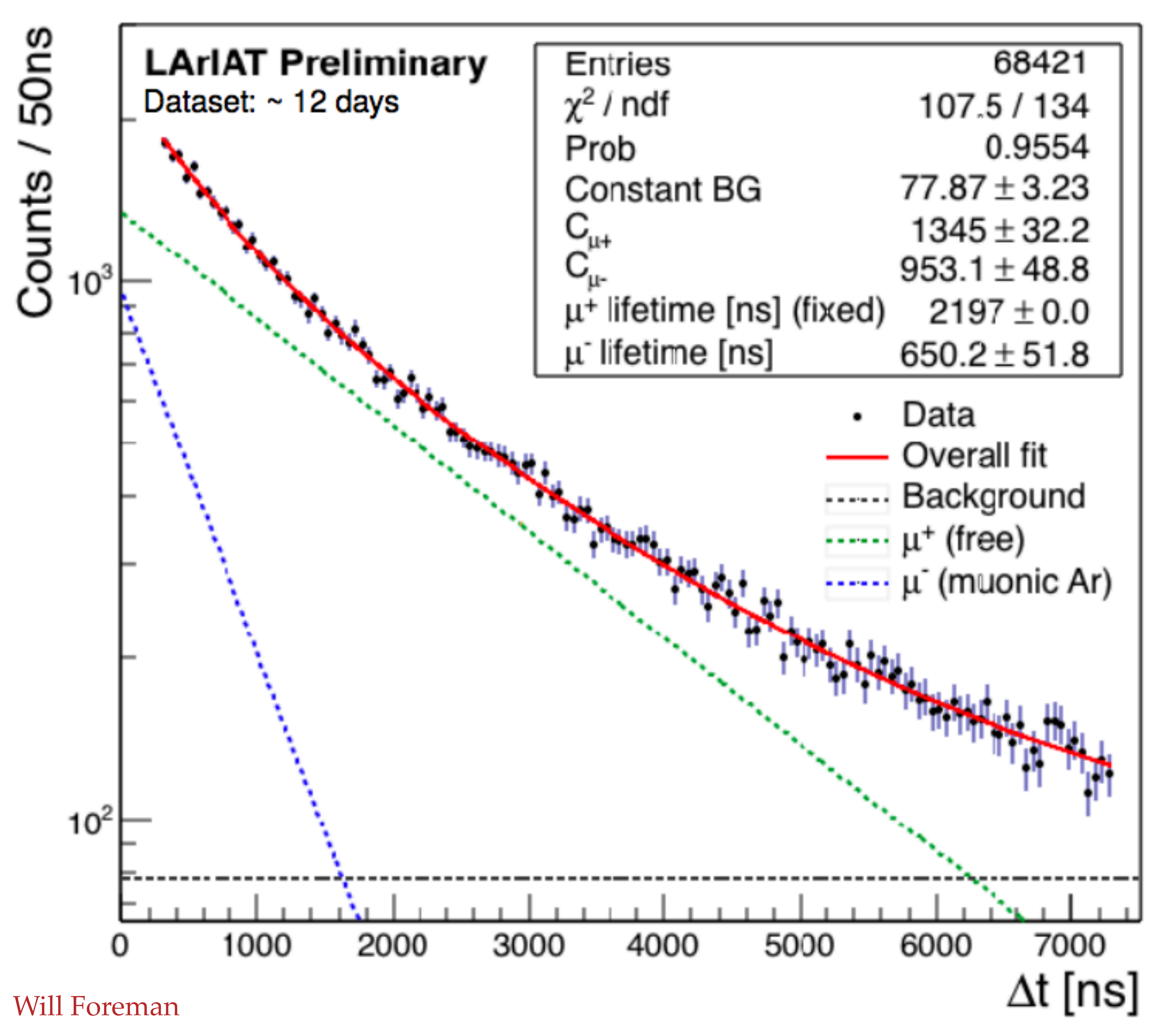
$$\tau_{\mu-} = \left(\frac{1}{\tau_c} + \frac{Q}{\tau_{free}}\right)^{-1}$$

650 ± 52 ns
(from fit result, preliminary)

918 ± 109 ns

- Early results agree with recent measurement[1] (854 ± 13 ns) and theory prediction[2] (851 ns)

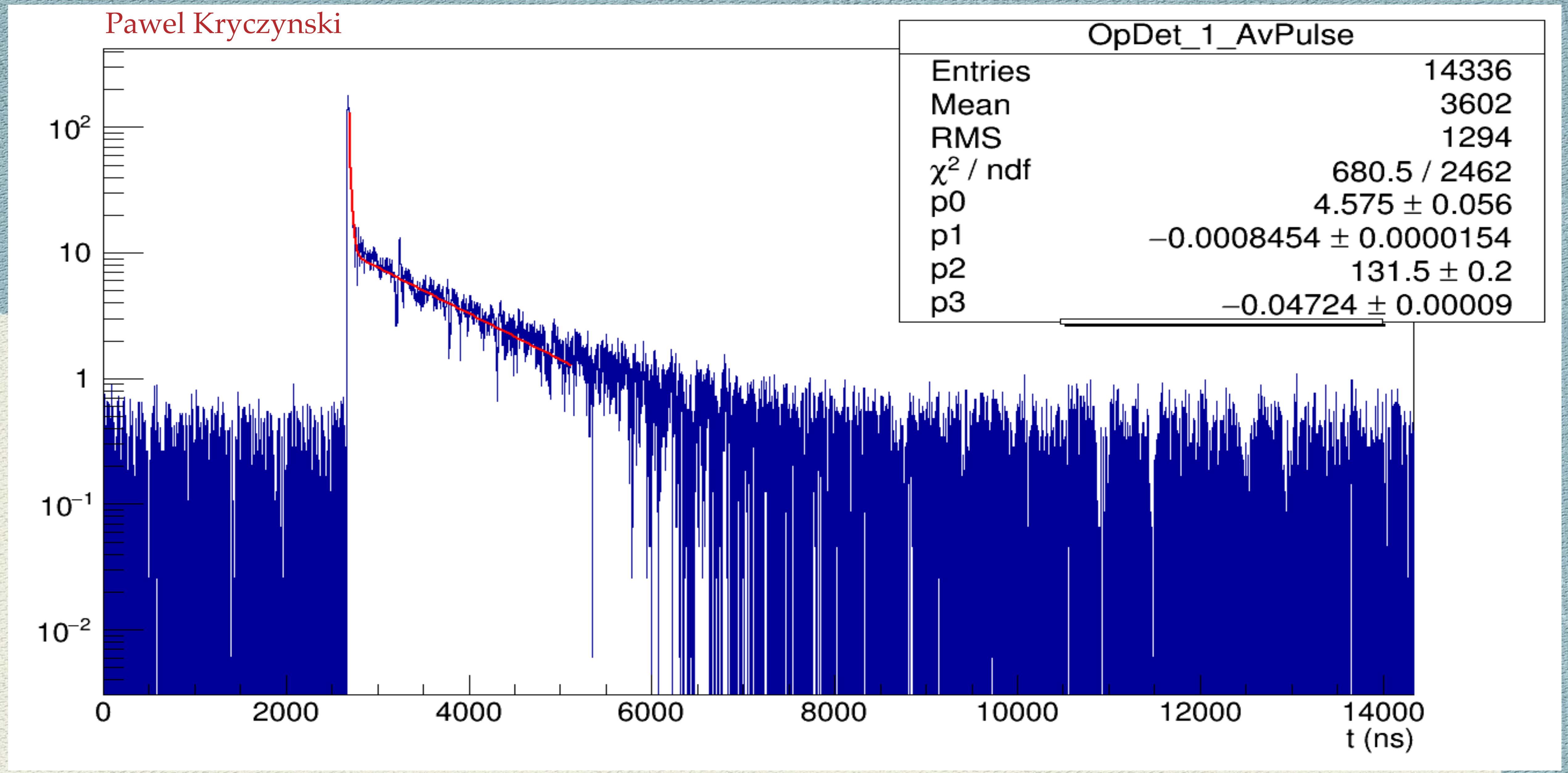
[1](Klinskih et al., 2008)
[2](Suzuki & Measday, 1987)

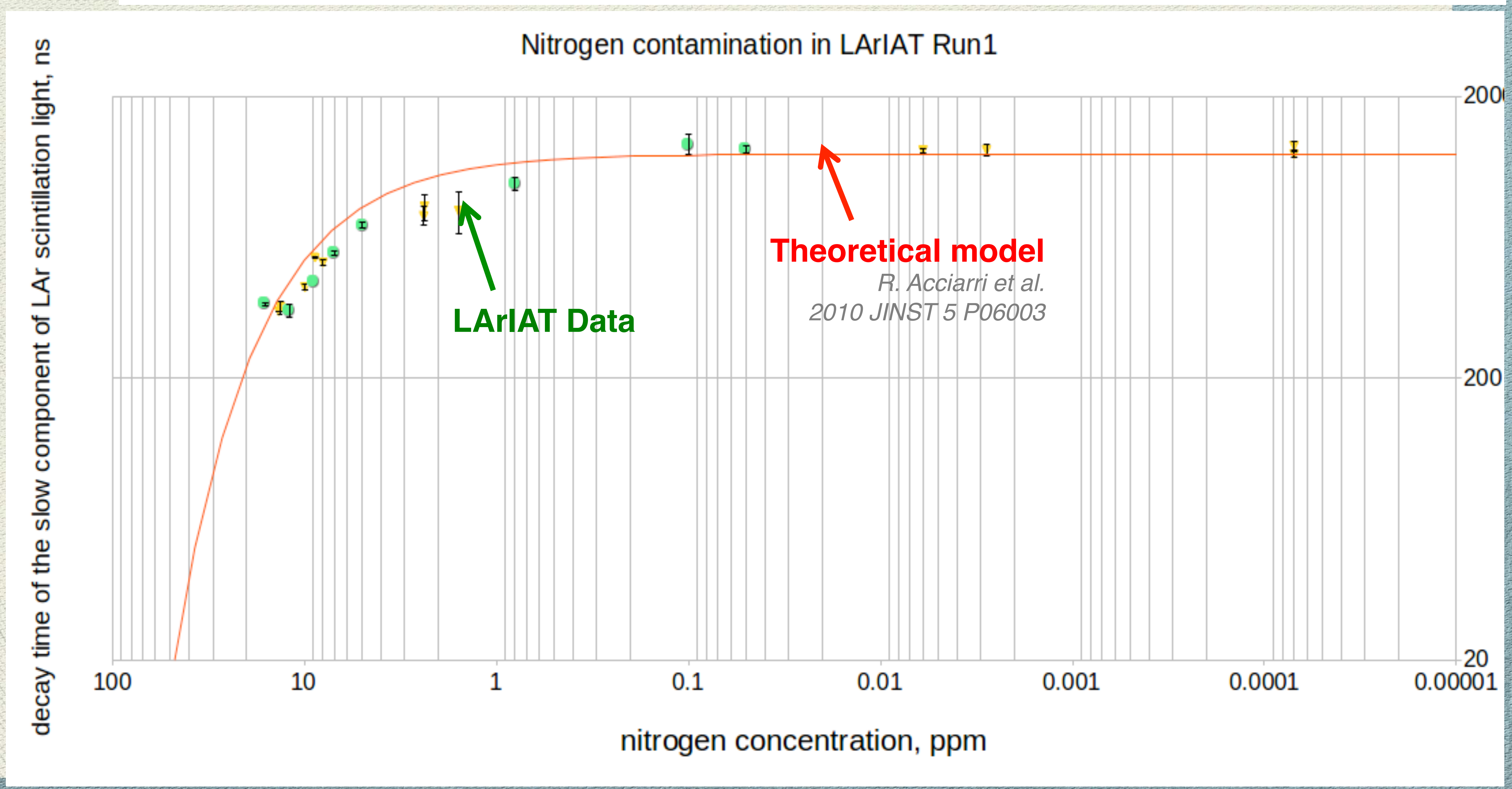


Neutrino vs. anti-neutrino
Statistical discrimination possible

N_2 contamination

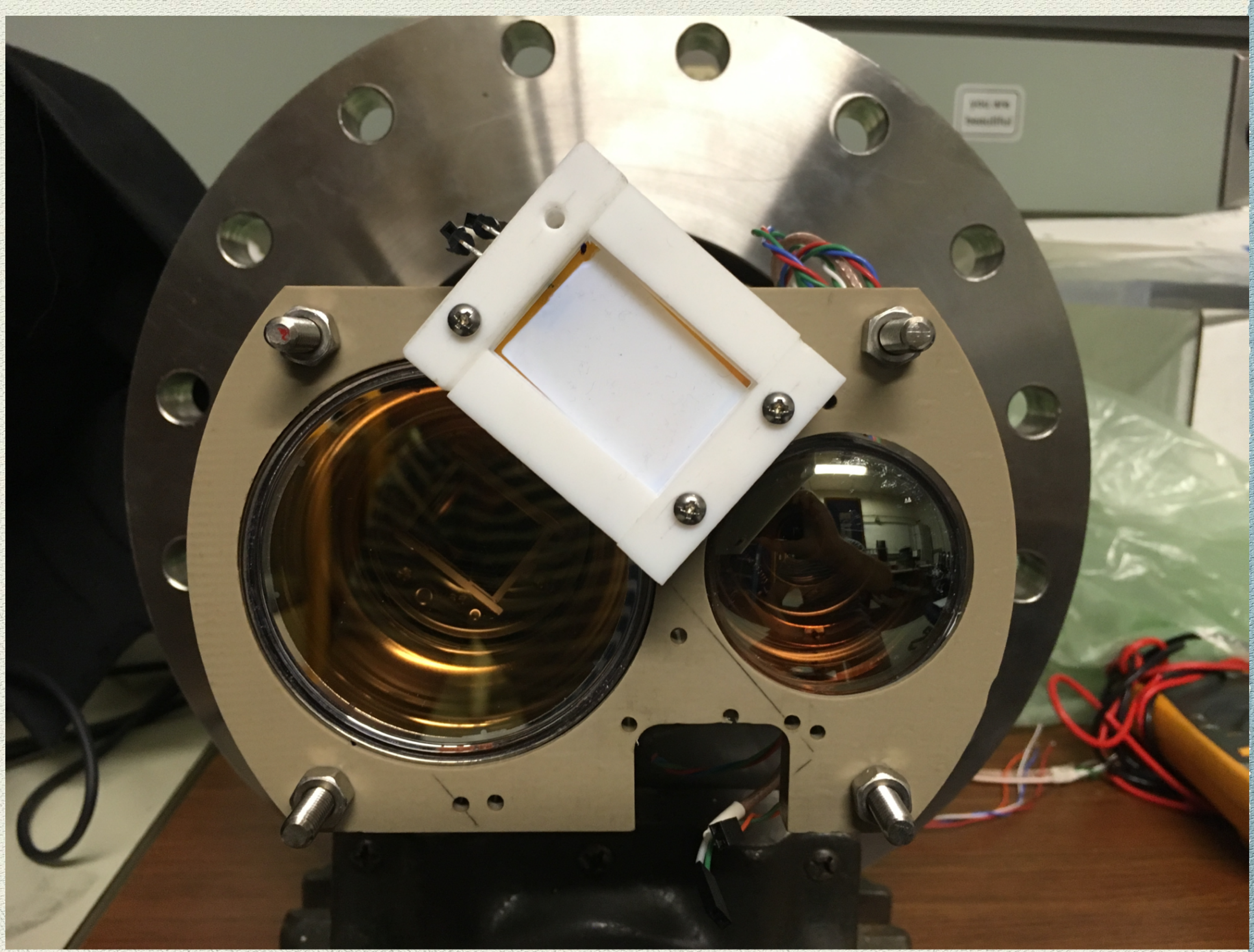
- N_2 in LAr suppresses scintillation light
- From fits to scintillation, we can extract “slow” time component and determine N_2 concentration;
- Results in agreement with trend from model.





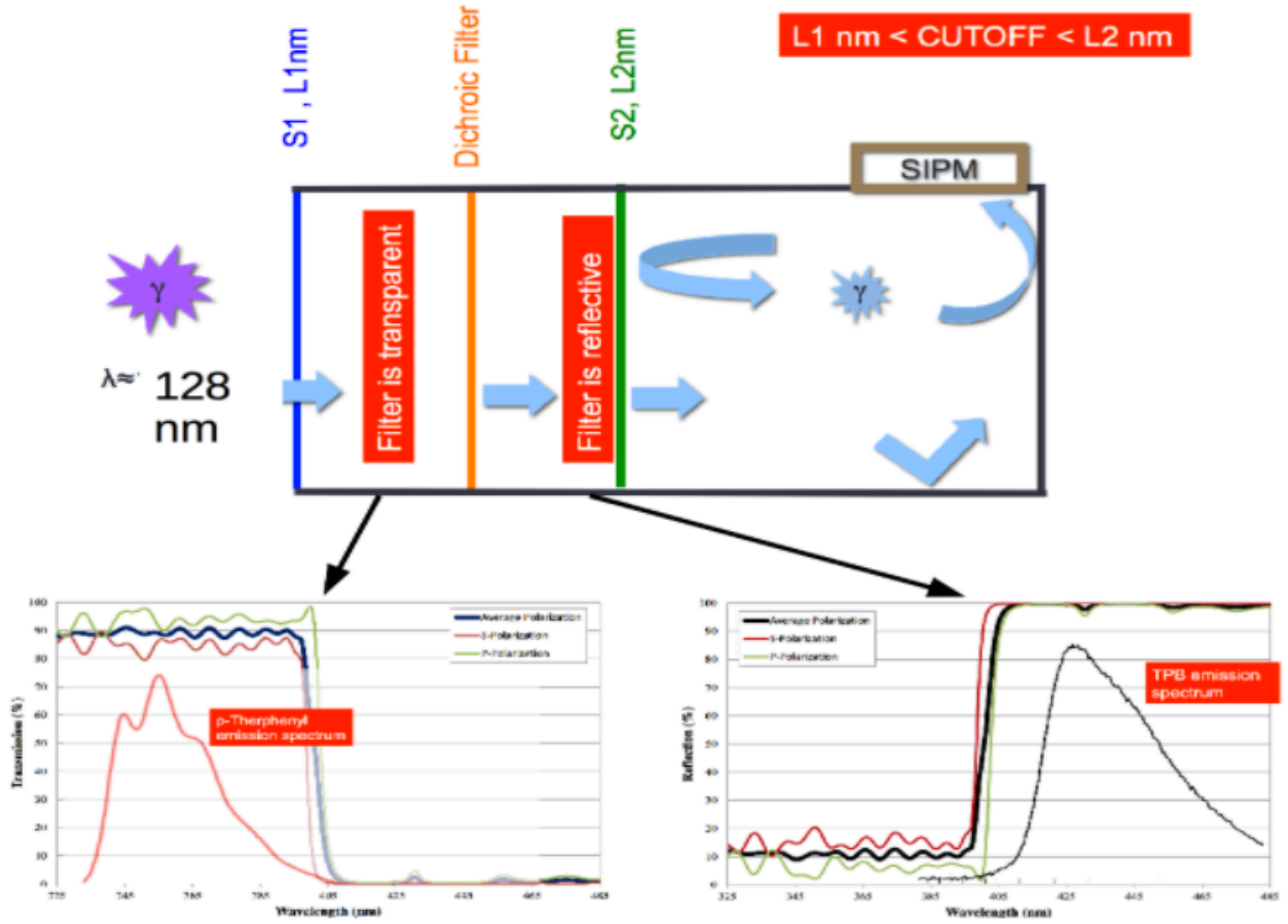
LArIAT Light Collection System - Run3

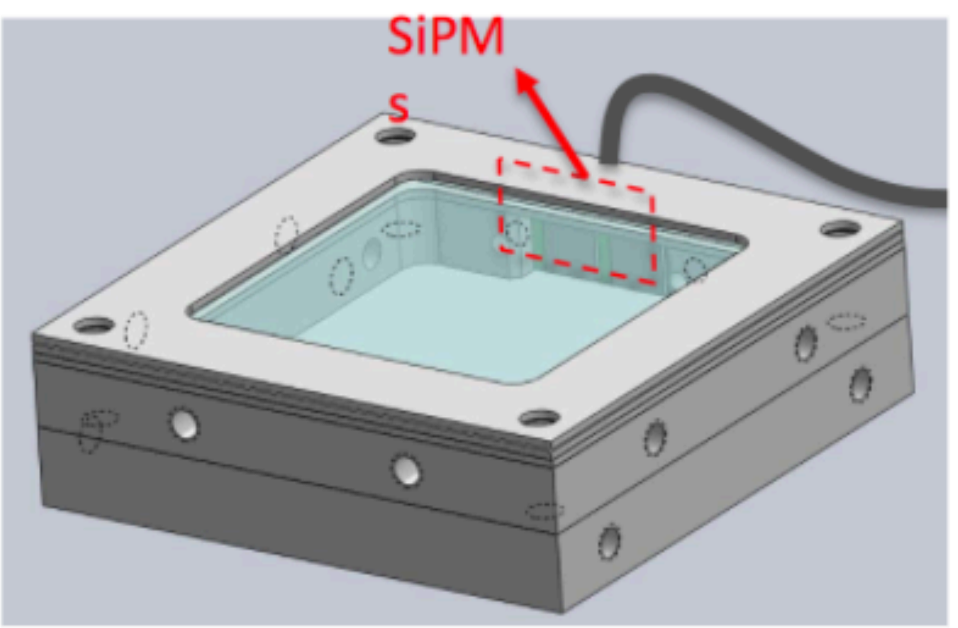
- On the third run was composed by:
  - 1 - 2” ETL PMT;
  - 1 - 3” Hamamatsu PMT;
  - 1 ARAPUCA!



ARAPUCA working principle

- VUV (128 nm) photons are produced in LAR
- 1st WLS interaction: downshift to $\lambda < \lambda_{CUT}$
    - Filter is transparent, photons get into the box
- 2st WLS interaction: downshift to $\lambda > \lambda_{CUT}$
    - Filter is reflective, photons become trapped
- Photons undergo further reflections until reach the photosensor (SiPM)

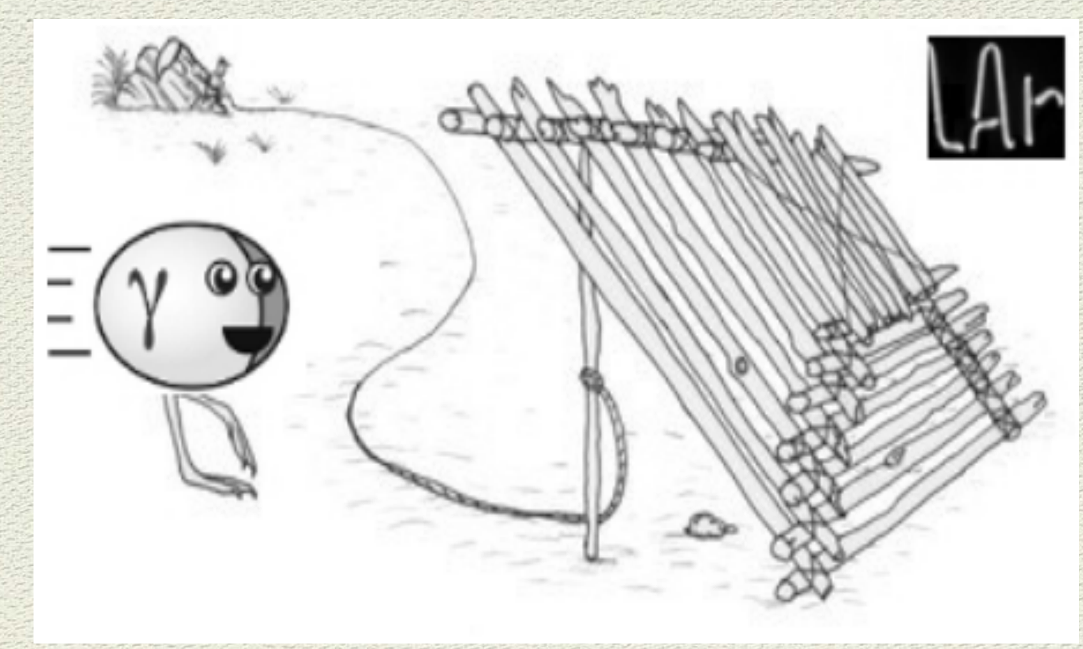


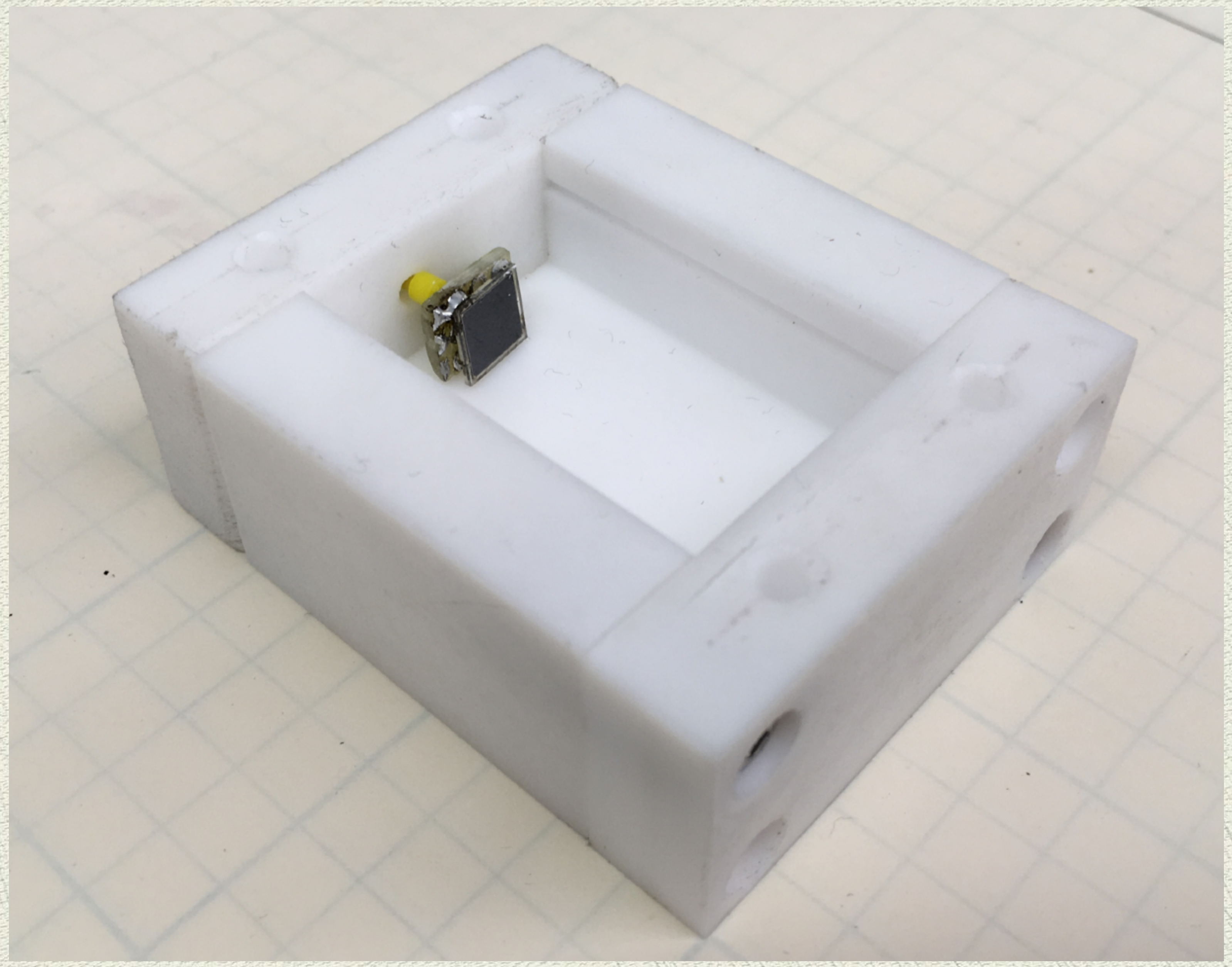


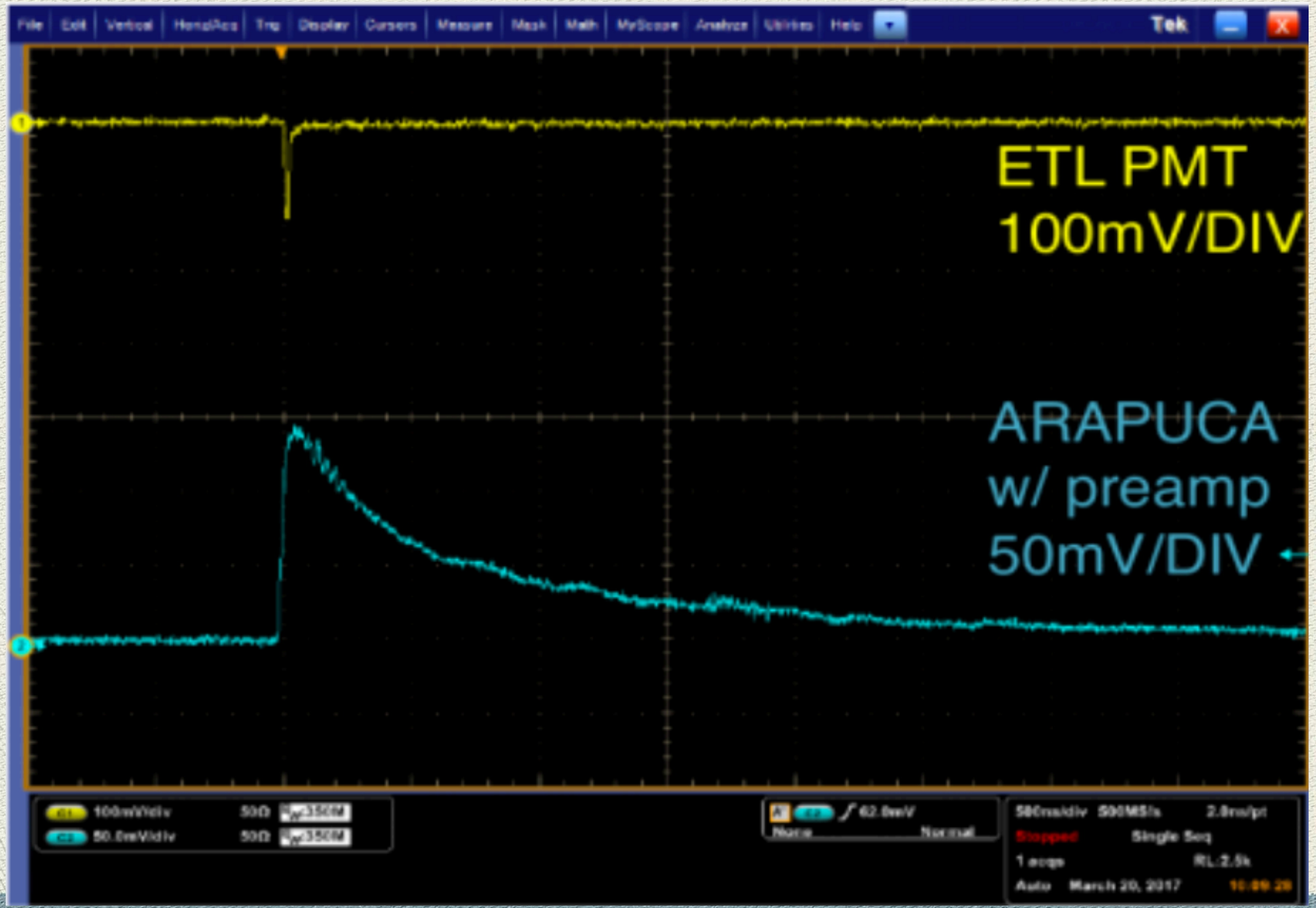
ARAPUCA a new device for liquid argon scintillation light detection. A. A. Machado, E. Segreto (Campinas State U.). JINST 11 (2016) no.02, C02004

Argon R&D Advanced Program @ UniCAmp

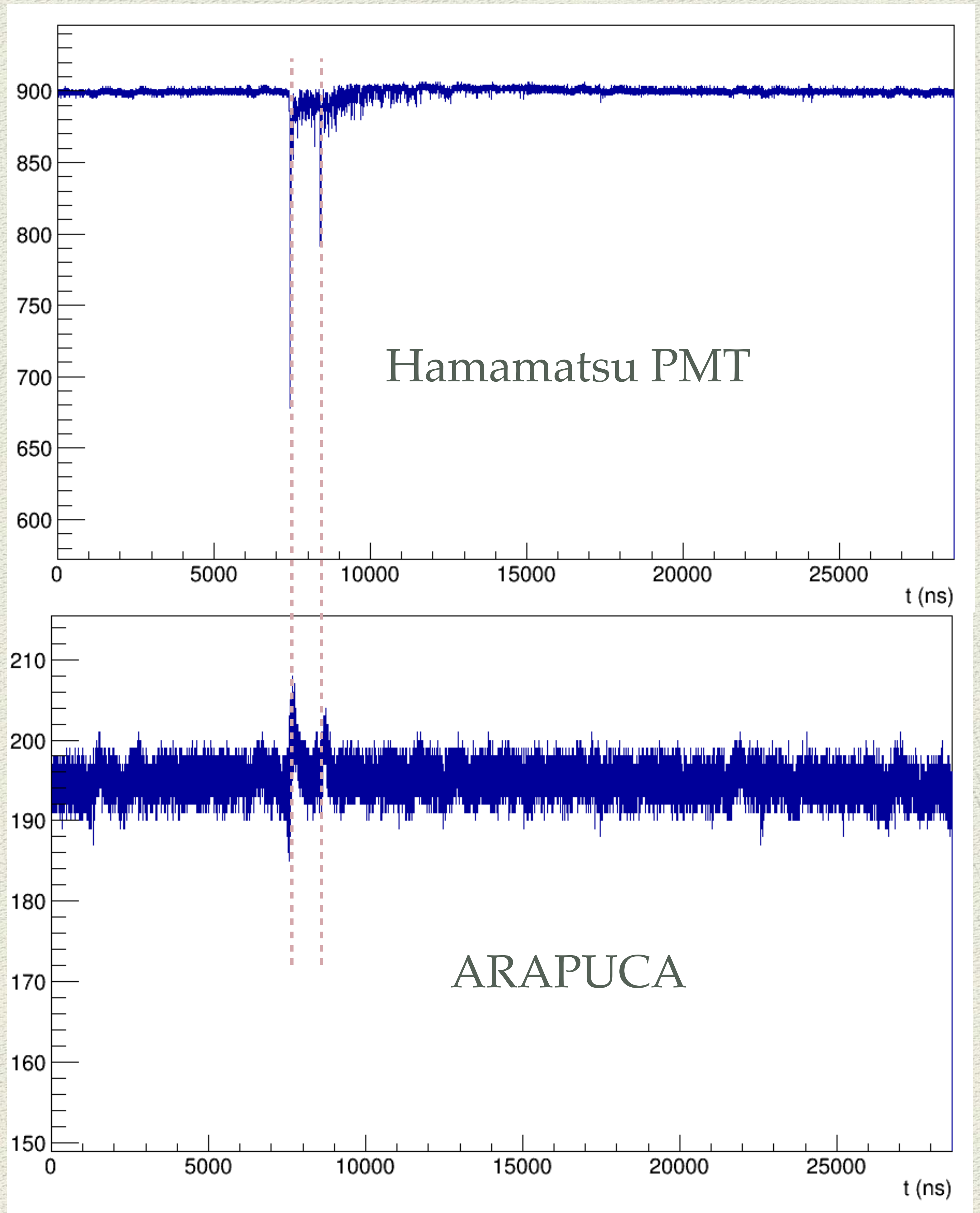
- Trap photons inside a teflon box with reflective surfaces;
- Window of 25.2 mm x 35.6 mm;
- After internal reflections, photons are detected by a SiPM (6mm x 6mm).





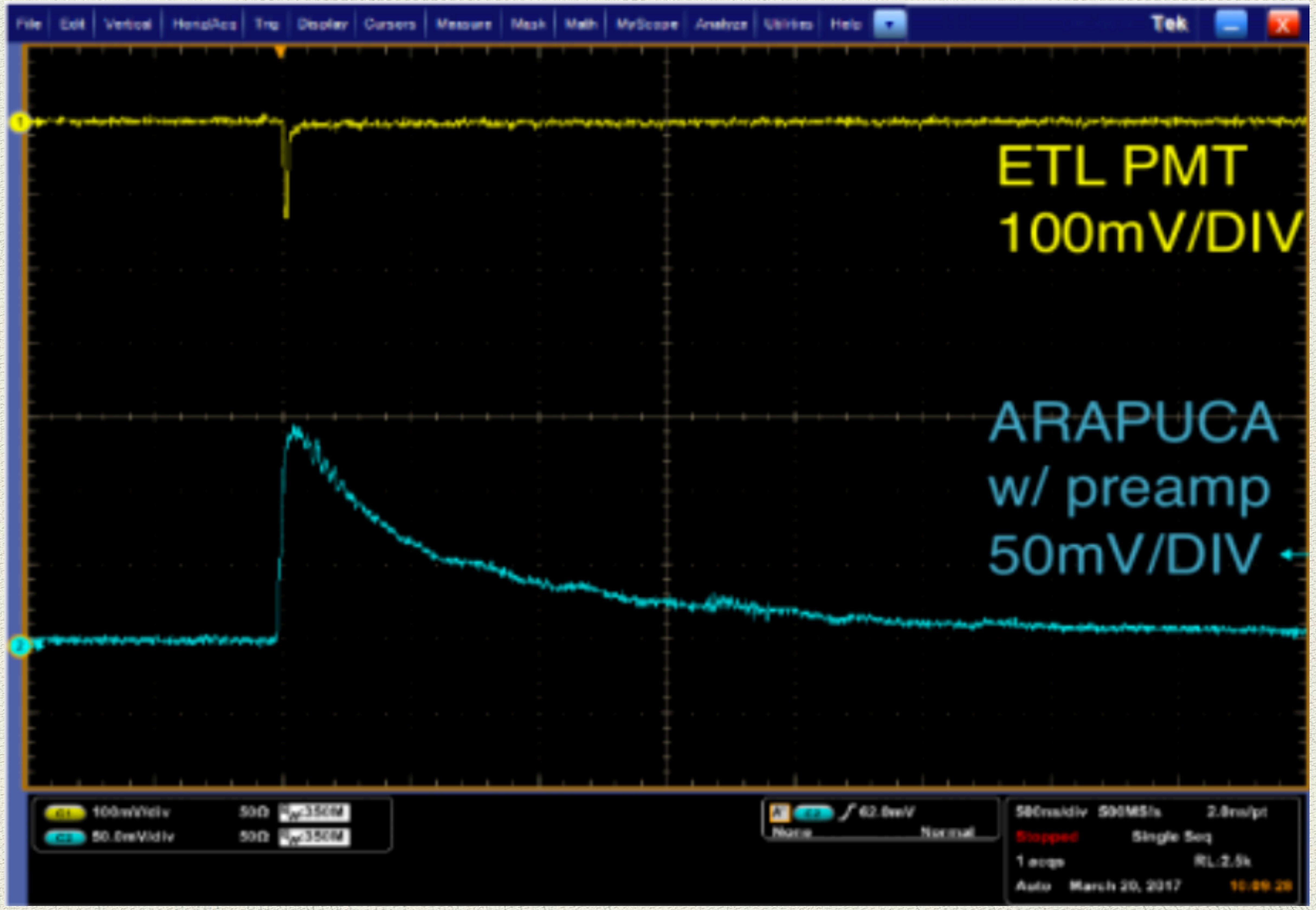


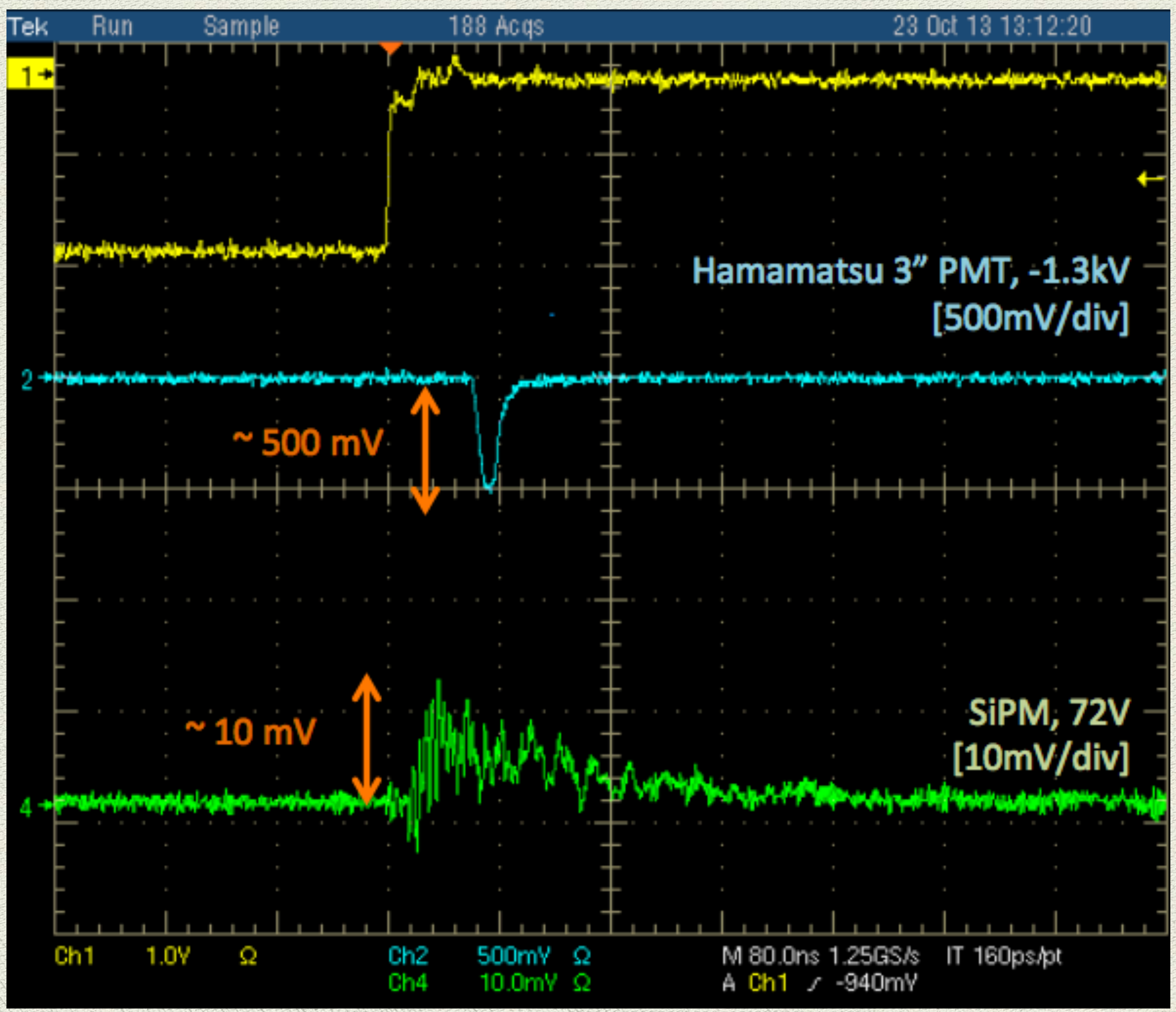
What do we see?



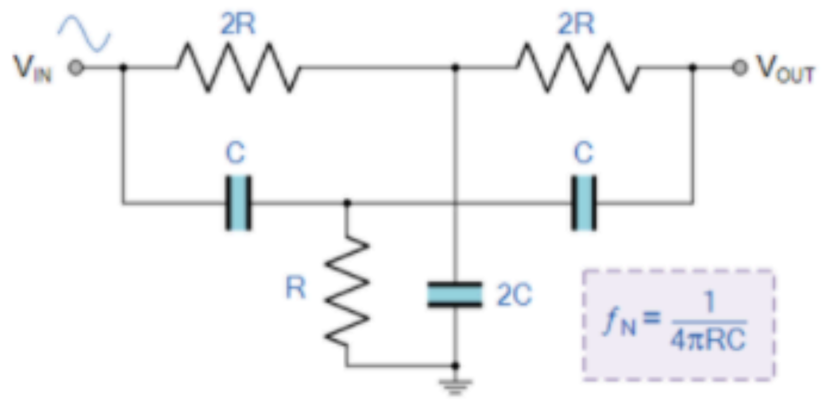
- ARAPUCA is able to see the same events as the PMTs
- The sensitive areas are different:
  - ~9 cm^2 for ARAPUCA (with a 6x6mm^2 SiPM)
  - ~45 cm^2 for Hamamatsu PMT

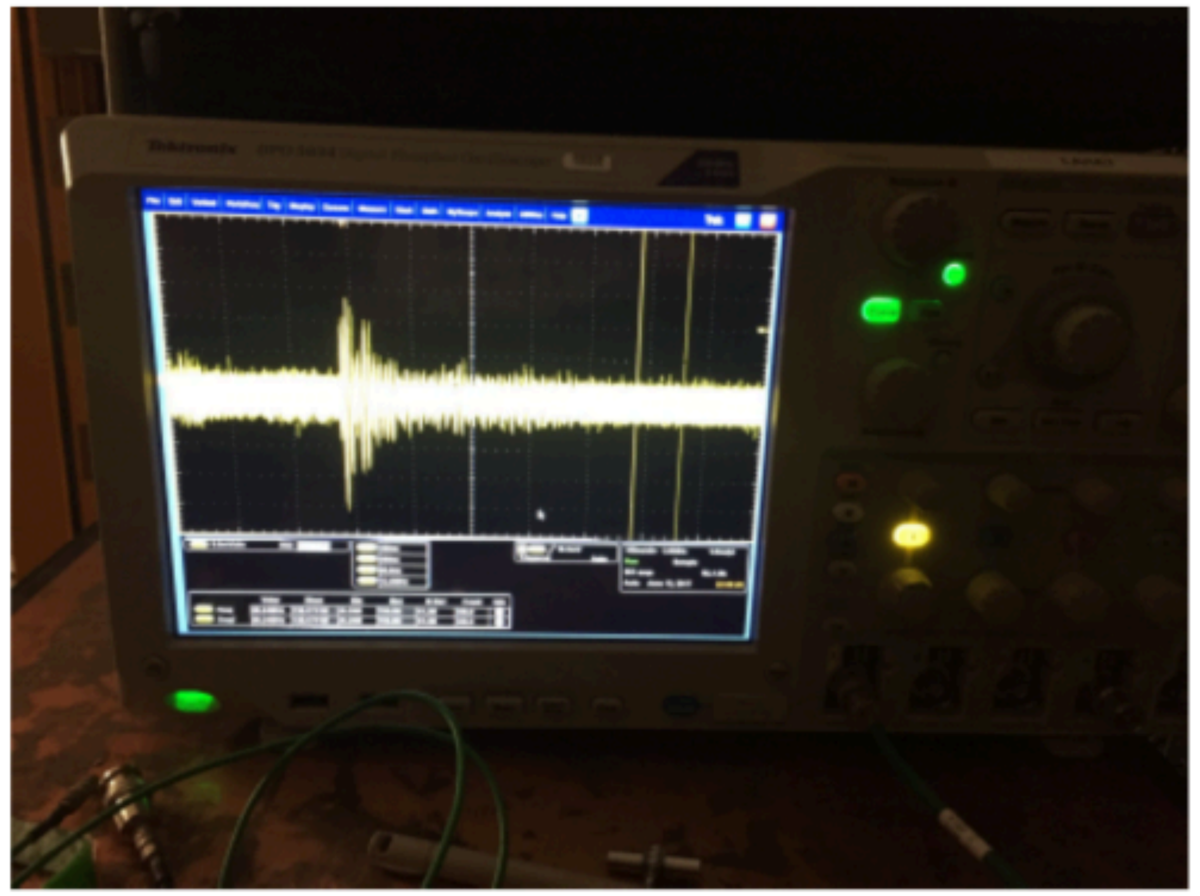
ARAPUCA vs (Bare) SiPM

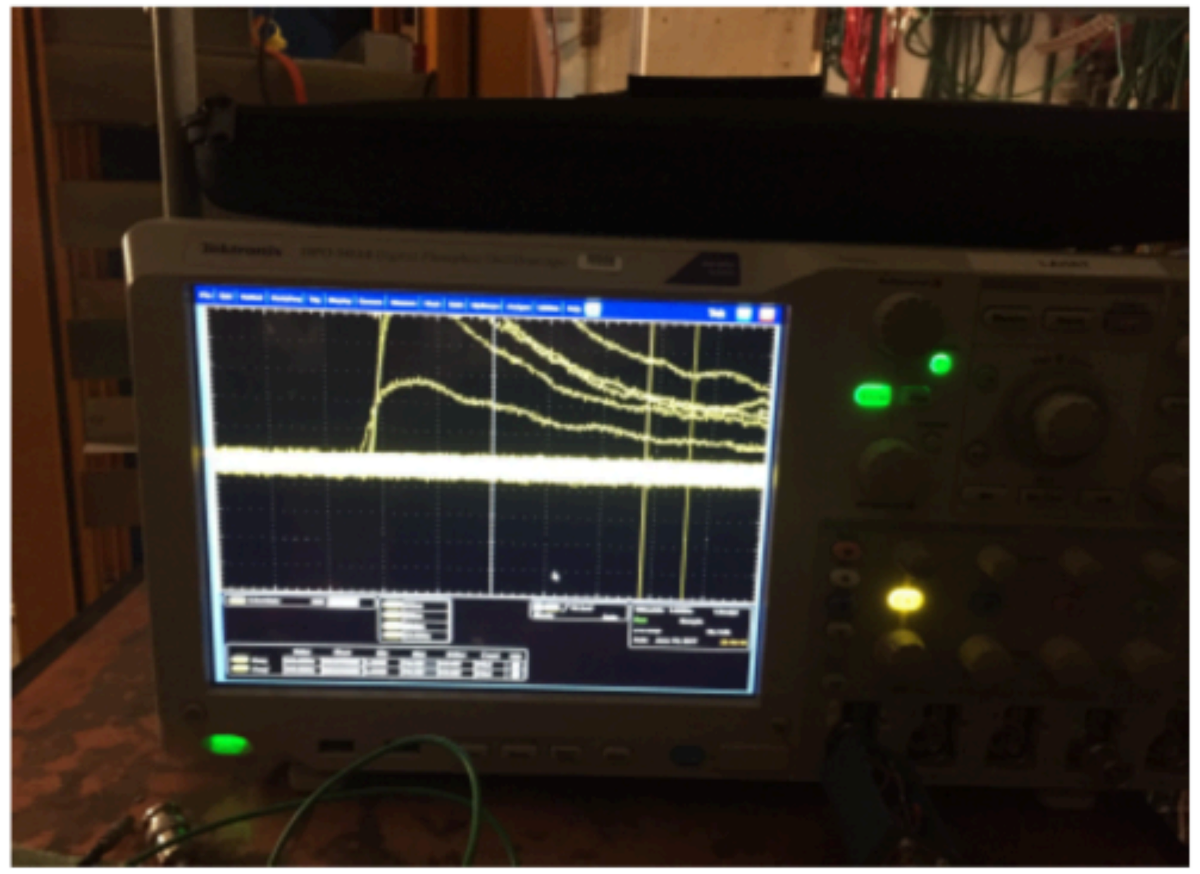


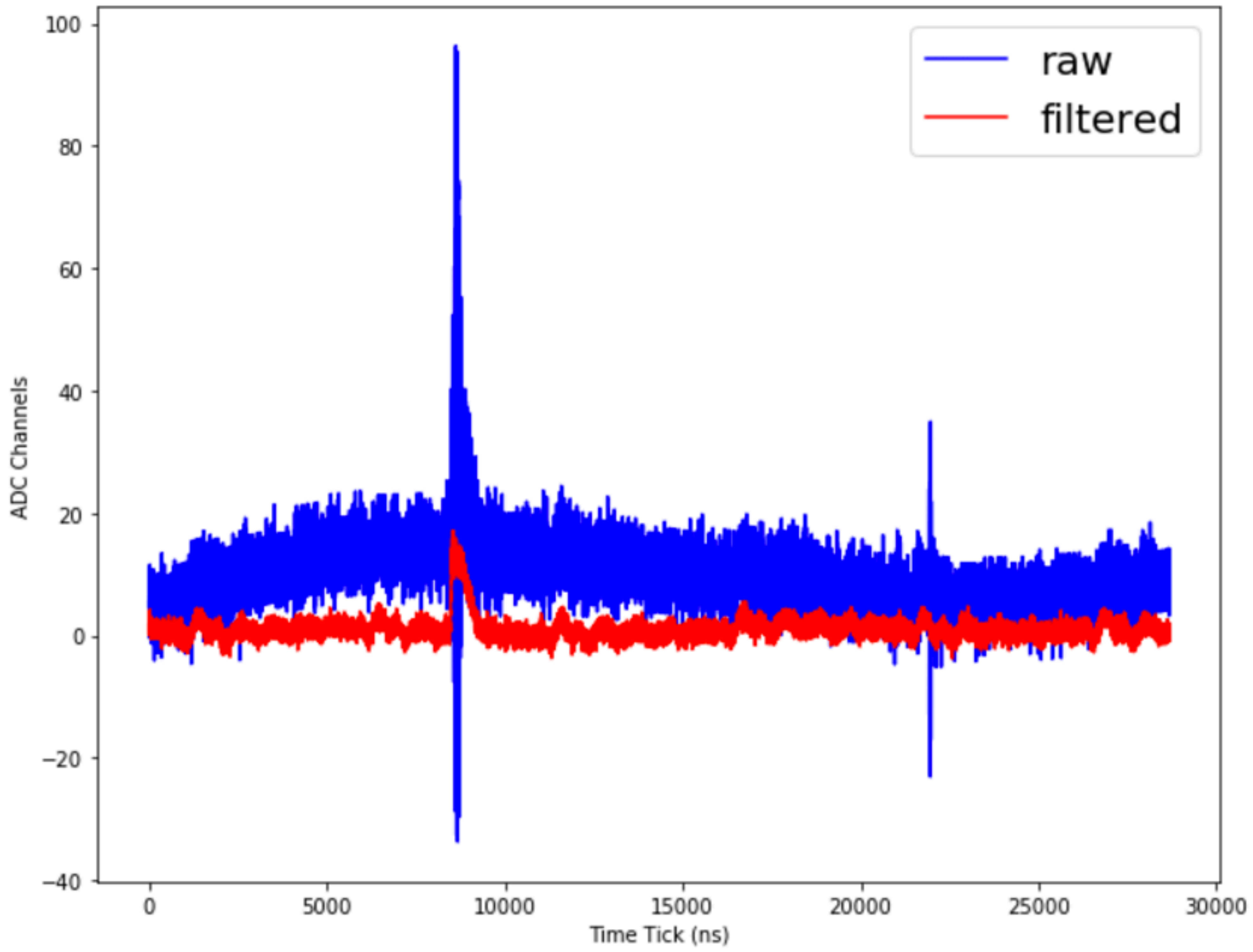


ARAPUCA: signal cleaning





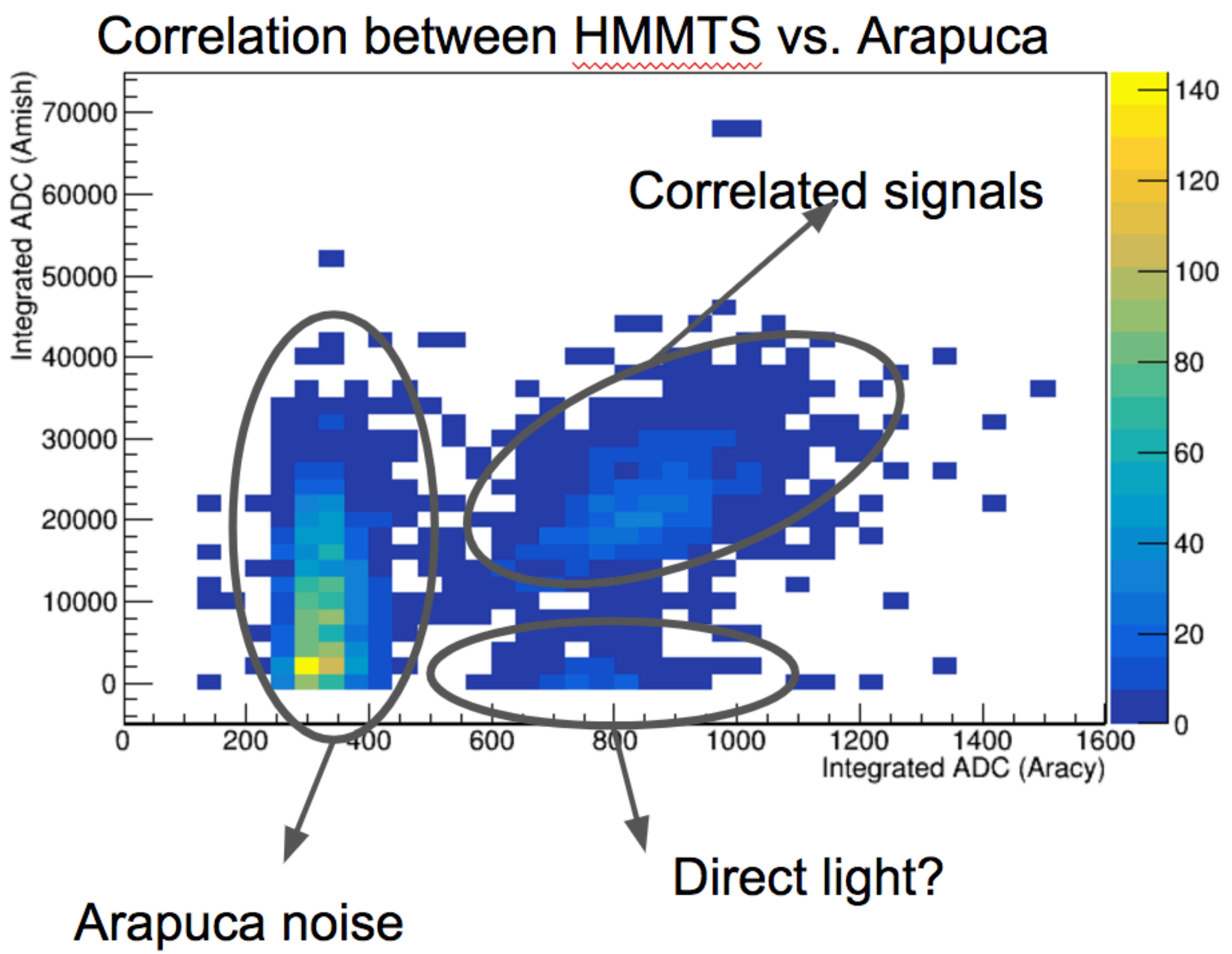




Hardware: Stop-band T-notch filter

Software: FFT/IFFT + smooth

Preliminary correlation: ARAPUCA vs. PMTs



Still under investigation…

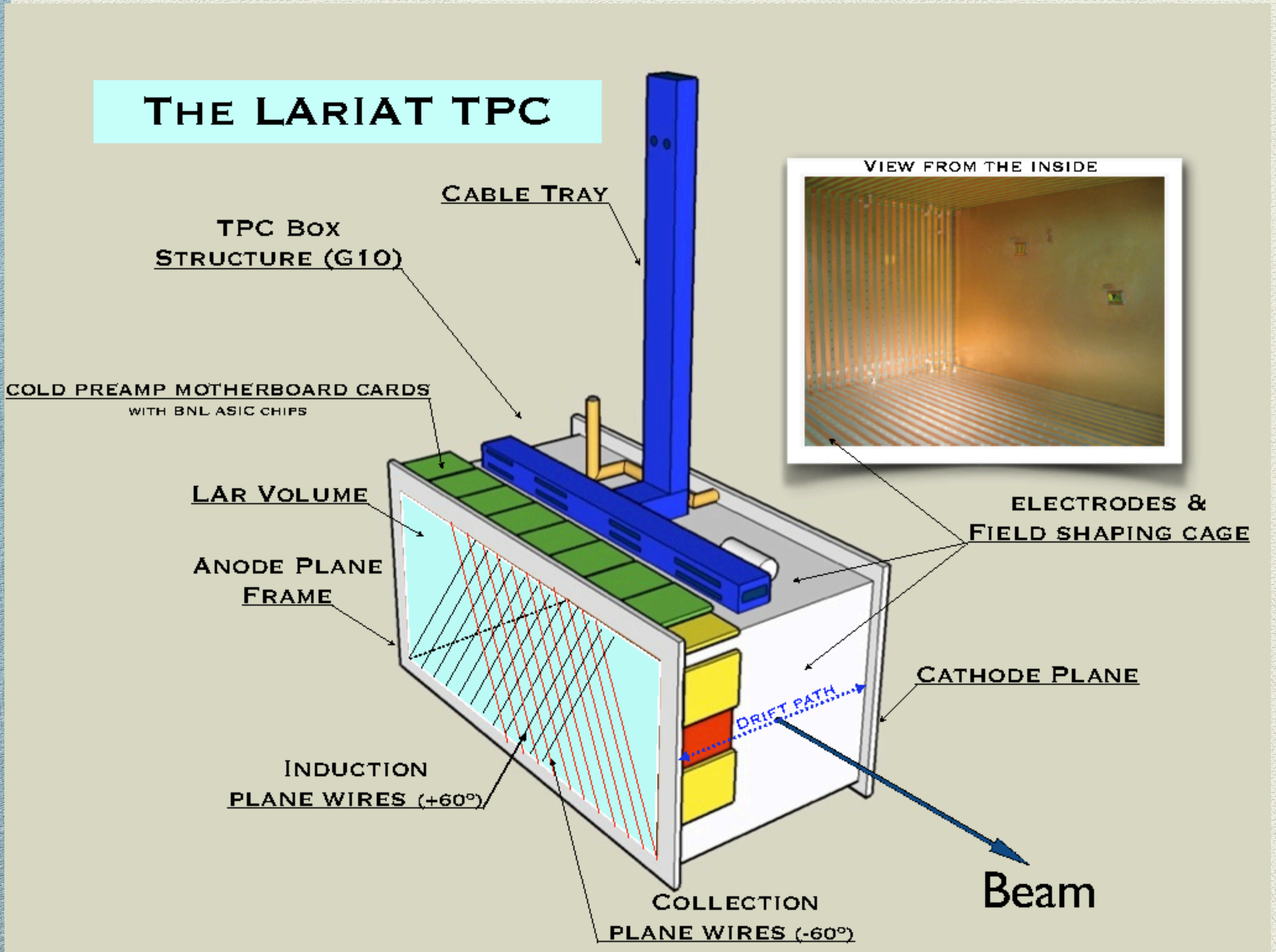
Time differences are going to be analyzed

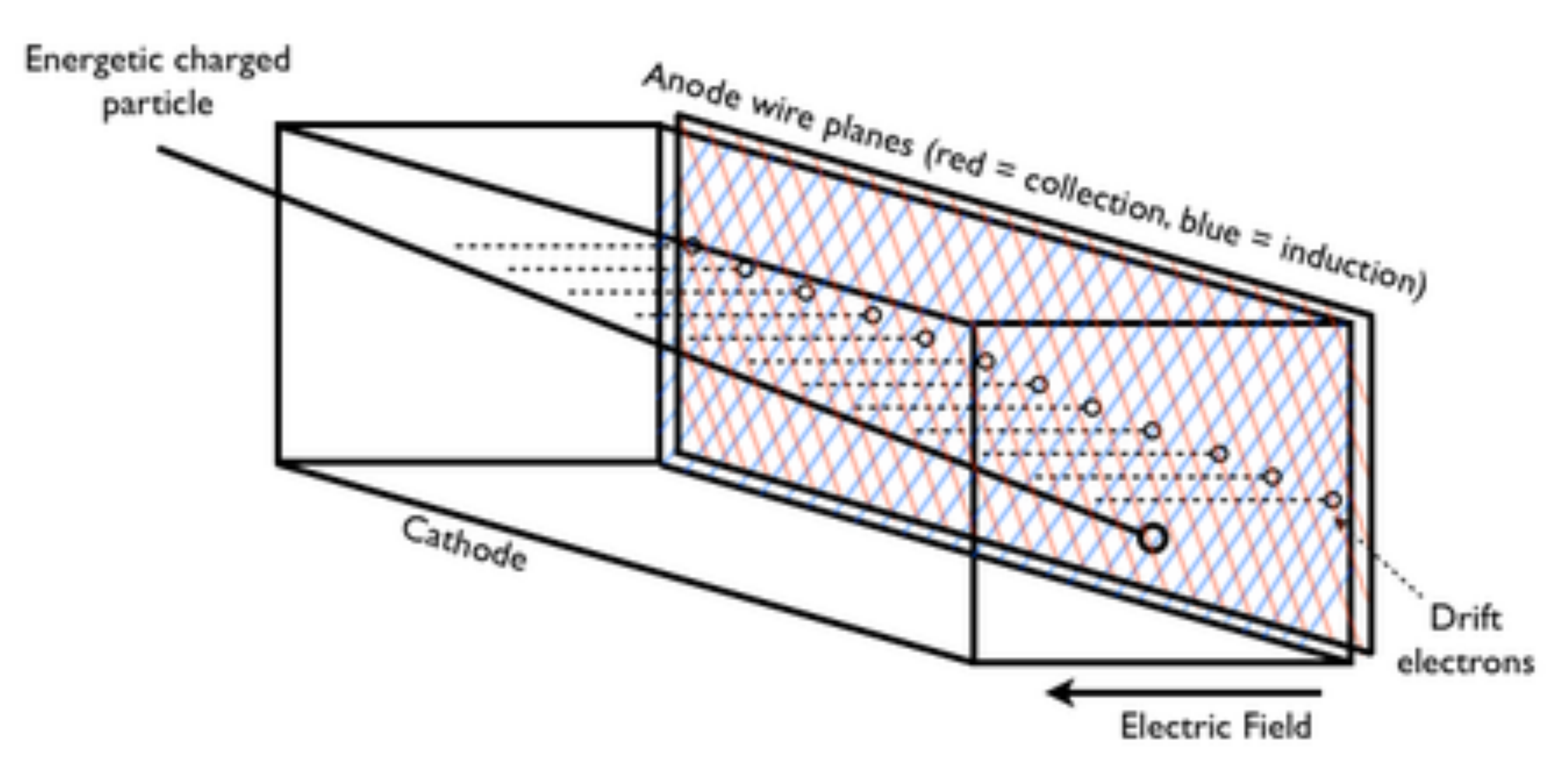
Conclusions

- Light plays an important role in LArTPCs (for triggering, calorimetry, etc);
- Different light detection systems are being studied in LArIAT with good results coming;
- It’s challenging to analyze Arapuca’s data - noise, small pulses, etc, but it’s possible and we are still going with studies!!
- Stay tuned!!!! We’re working hard to get good new results!
- Aknowledgements: Monica Nunes and Andrzej Szelc for help with slides content

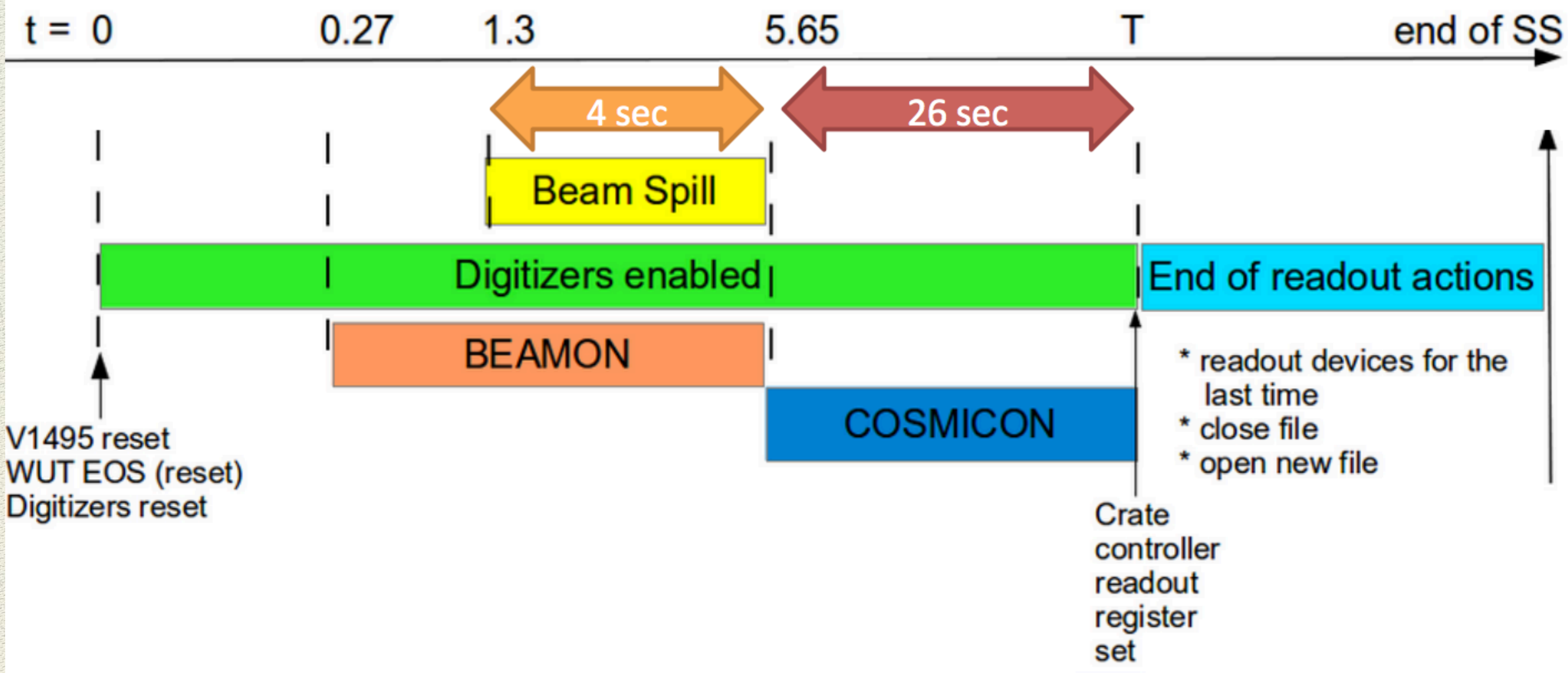
Backups

How does a LArTPC works?!



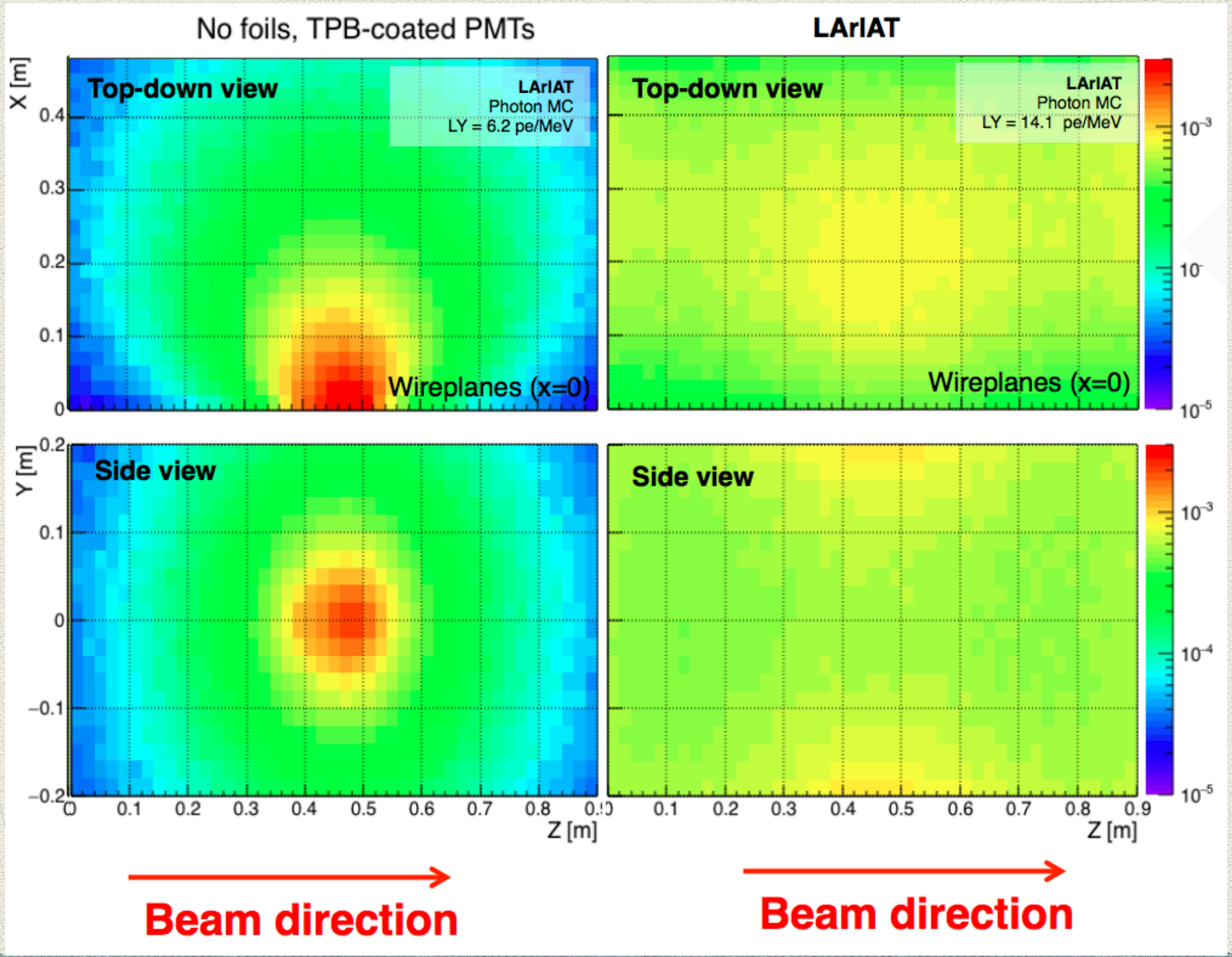


LArIAT cycle

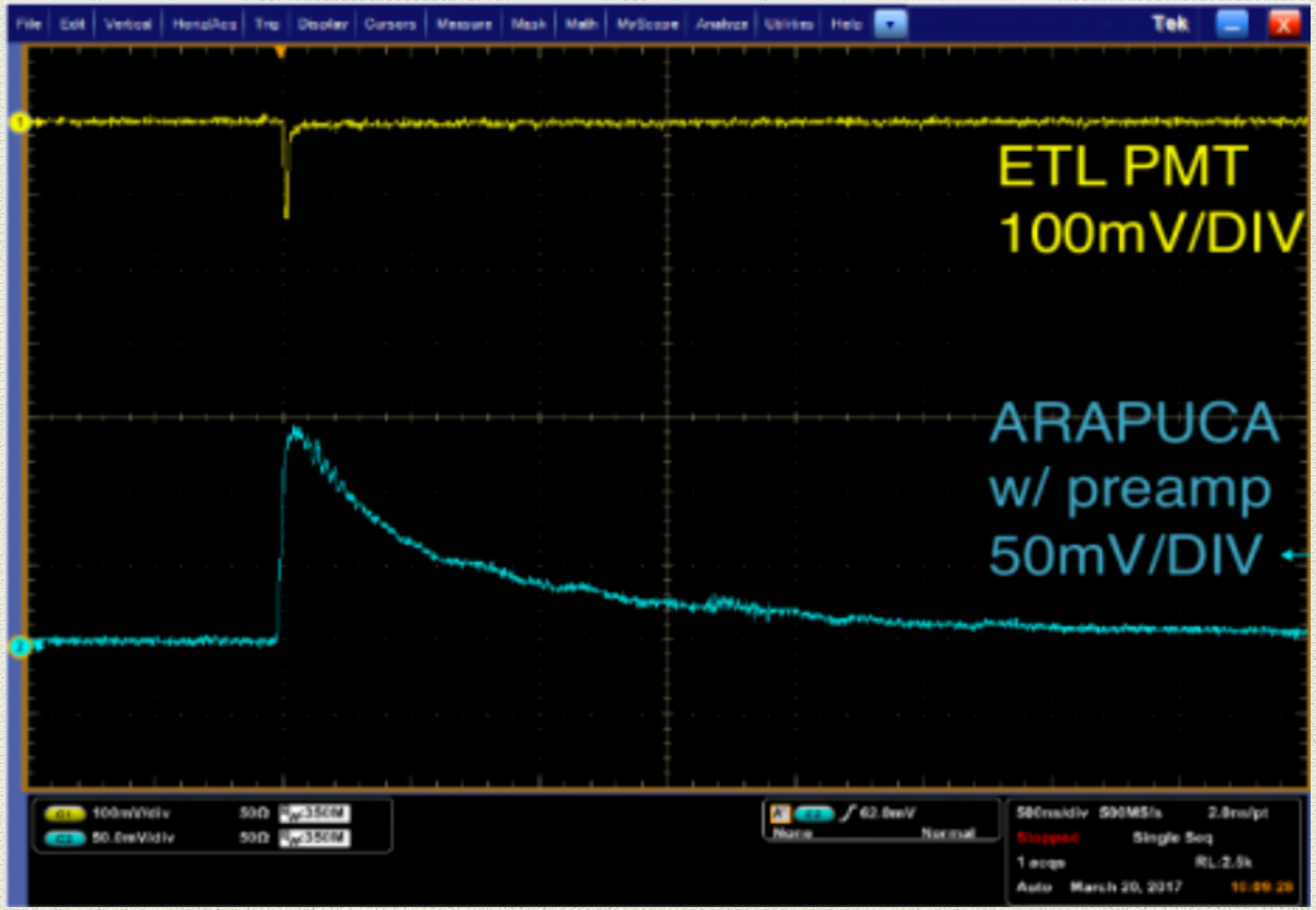


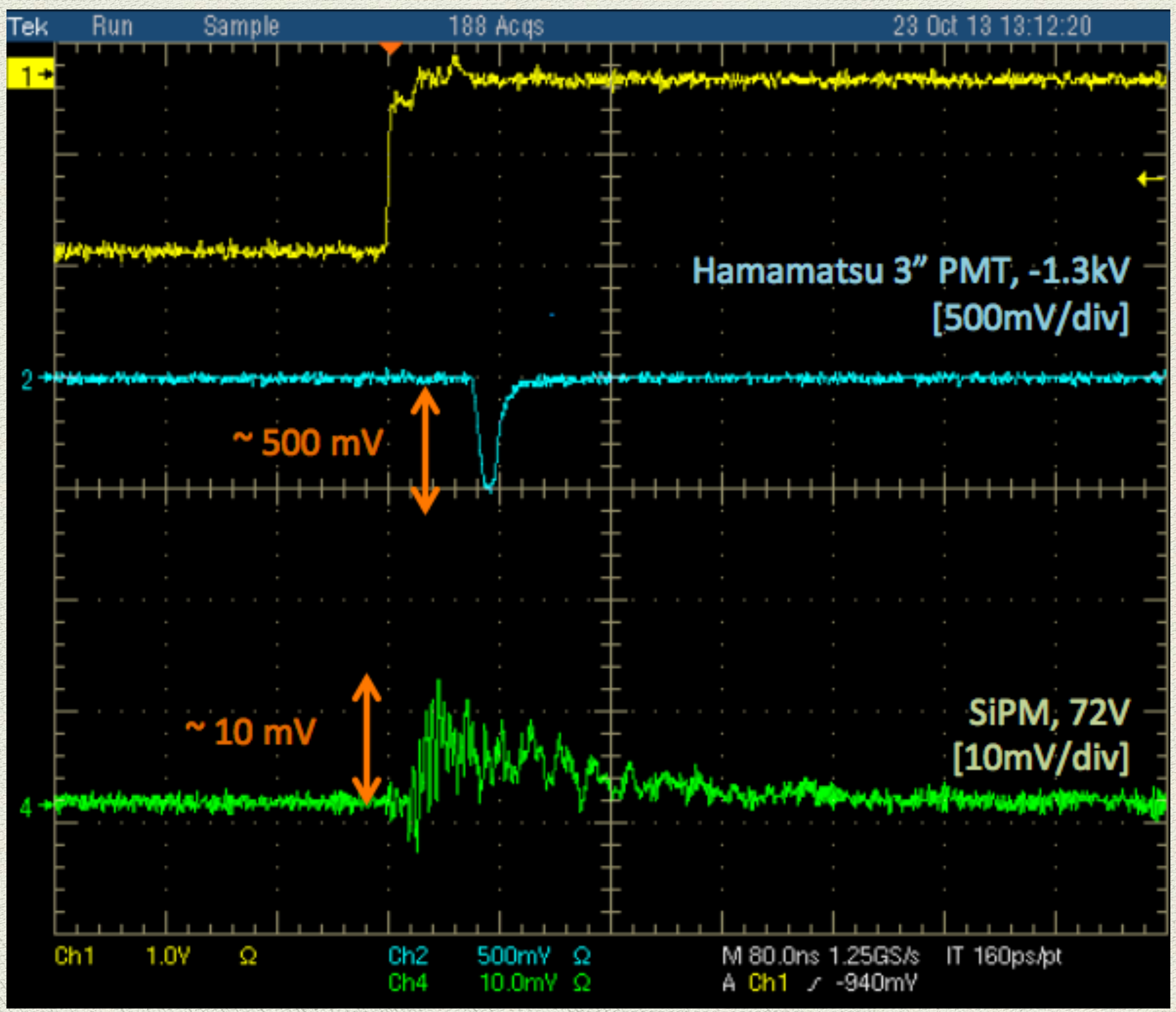
Spill supercycle = **4s beam + 24s cosmics & light-based Michel triggers**

Other experiments LCS vs LArIAT solution

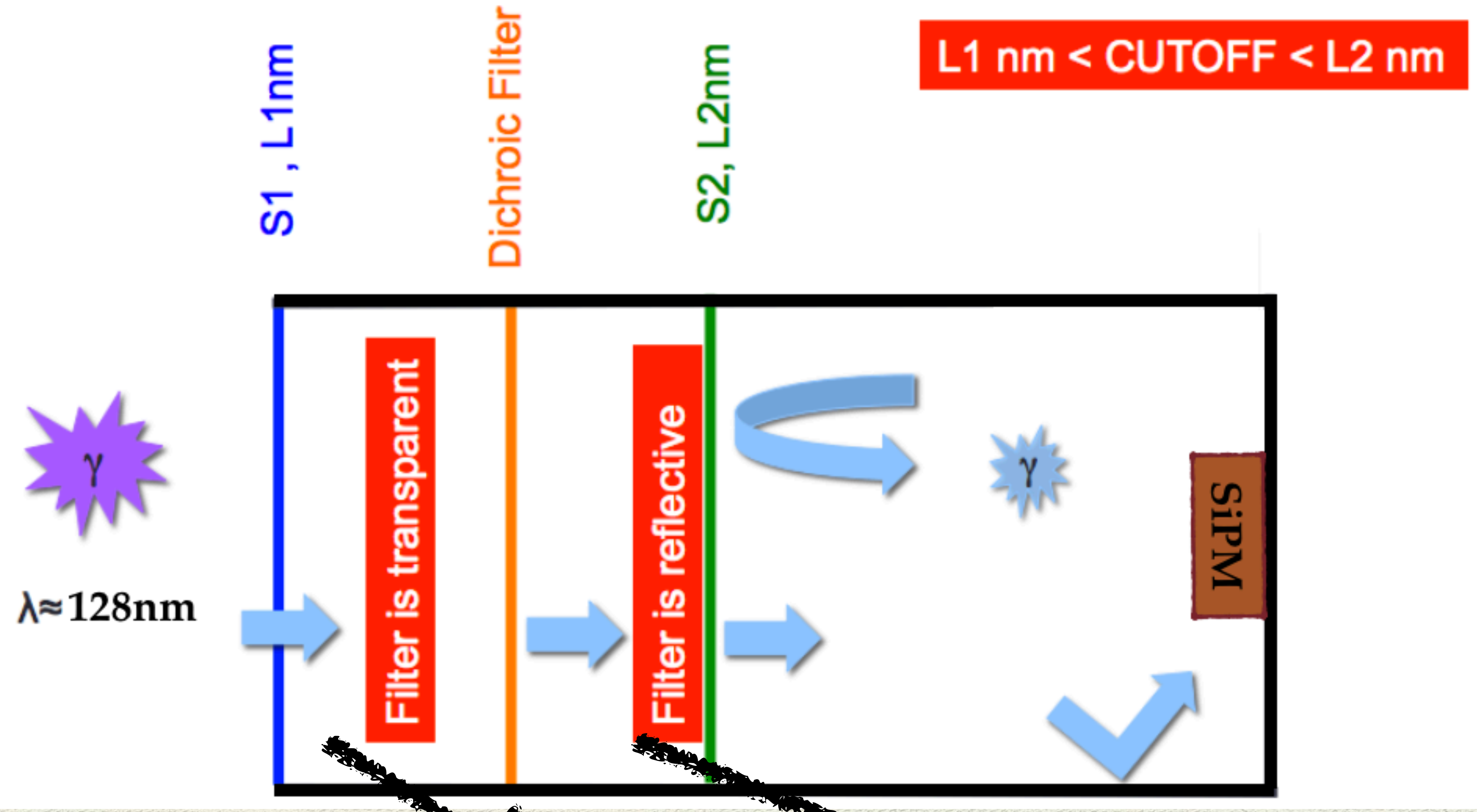


ARAPUCA vs (Bare) SiPM

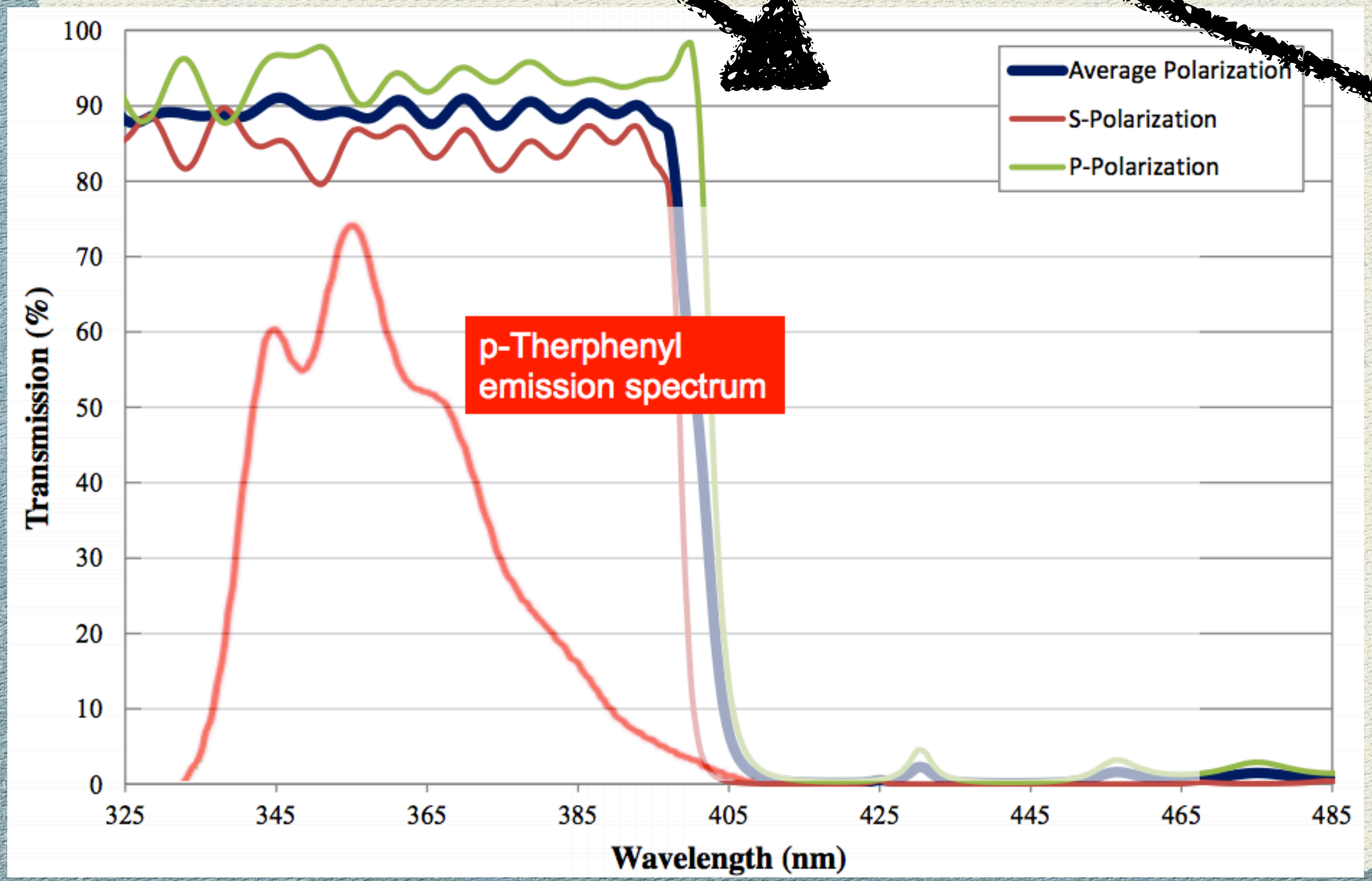


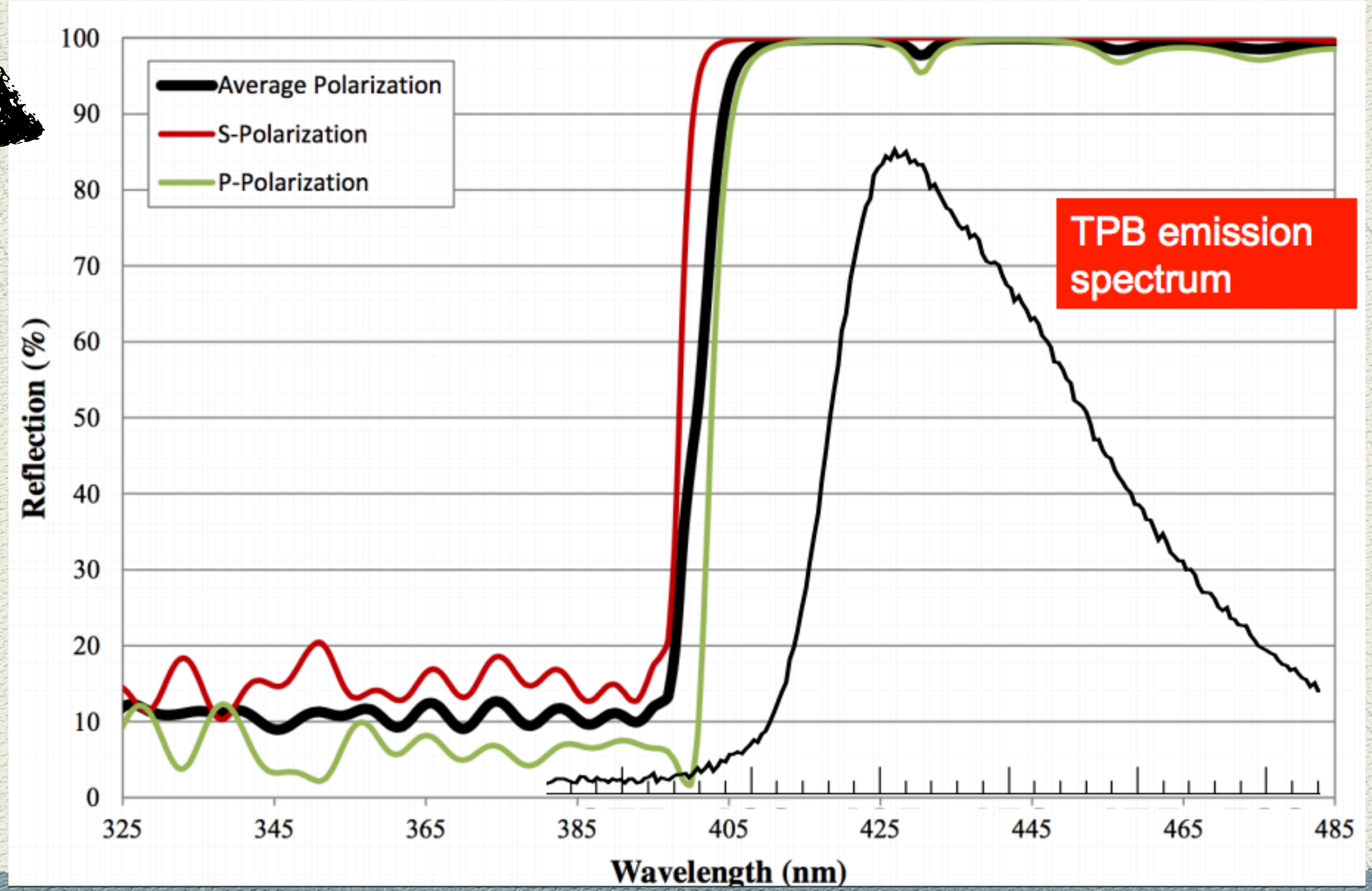


ARAPUCA - How does it work?



- Light from scintillation = ~128 nm;
- After the first shifter = ~350 nm (bellow the filter cutoff);
- After the second shifter = ~430 nm (above the filter cutoff);





- Light gets trapped inside the box!

Arapuca - First Prototype

The first Prototype

- We realized a ***small prototype*** of ARAPUCA with a window of **3.5 cm x 2.3 cm**
- The box is made of **teflon** and has an internal height of **1 cm**
- The *dichroic filter* has a ***cutoff of 400 nm***
- We used as shifters ***P-Terphenyl*** (**λ ~ 350 nm**) for the *external side* and ***TPB*** (**λ ~ 430 nm**) for the *internal one.*
- We are installing a **3x3 mm^2** SiPM for detecting trapped light.
- We expect a **total detection efficiency** for 127 nm photons ***around 2%*** (evaluated with analytical calculation)