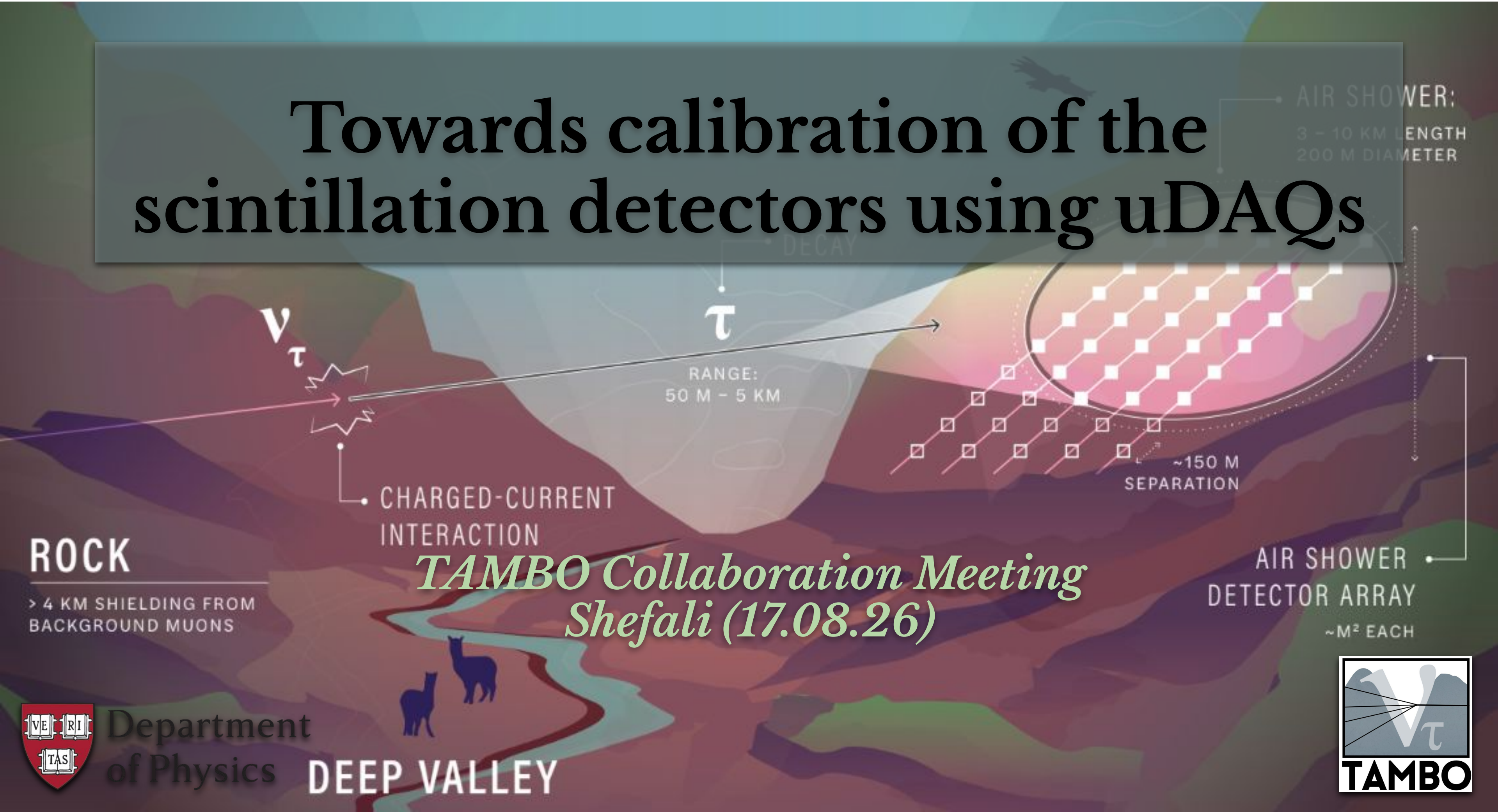
Towards calibration of the scintillation detectors using uDAQs



TAMBO Collaboration Meeting

Shefali (17.08.26)

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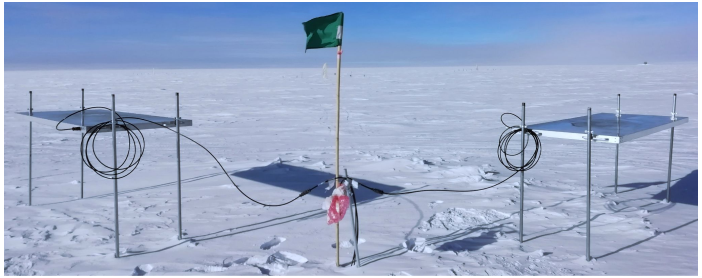
About Me

- Started as a Postdoc at the Harvard group in July 2026
- My PhD was focused on everything hardware and data analysis with the scintillation detectors for the IceCube Surface Array Enhancement at KIT, Germany
- During my masters I did the mechanical design of the acoustic calibration detector for the IceCube Upgrade RWTH Aachen University, Germany
- I like plants, and being in the nature whenever I get the chance :)

Acoustic Pinger



SAE Scintillation detectors

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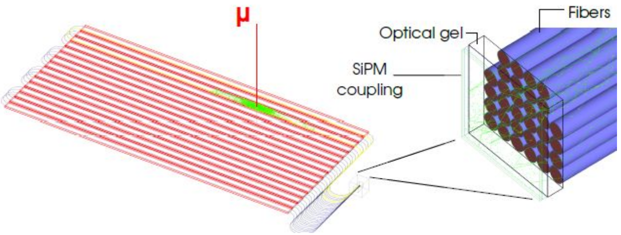
Status Quo

- In the virtual meeting and the panel review scintillation detectors readout by SiPM + uDAQ were finalised for the prototype design
- Challenges: For shower reconstruction and all the cool physics, we first need to calibrate the system
  - SiPM gain is inversely proportional to the ambient temperatures
  - We have a lot of natural background that masks our signal
  - uDAQ has limited functionality: dynamic range, buffer and more
- I have been working with uDAQs to understand the caveats and possible ways forward



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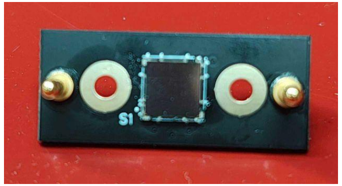

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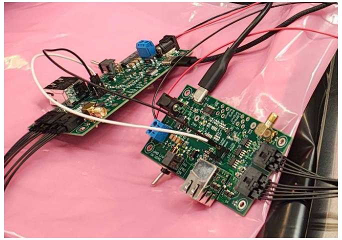

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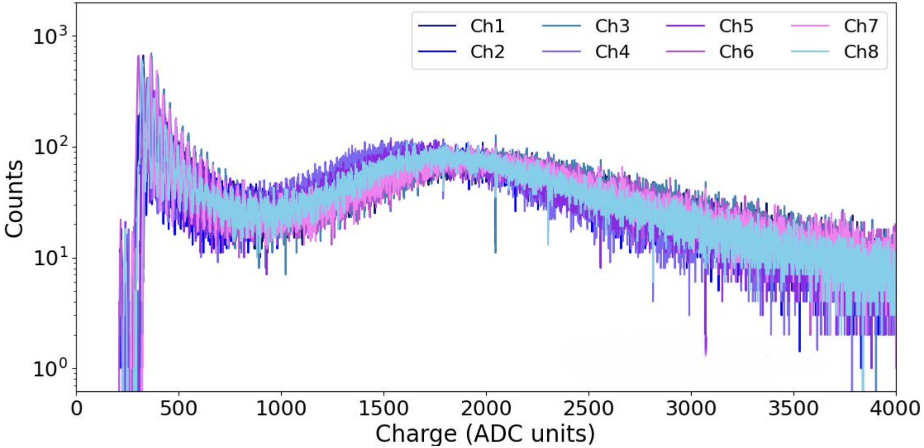
How can we calibrate the detectors?

- Minimally Interacting Particles (MIPs) deposit roughly the same energy when traversing the detectors, leading to a characteristic peak
- At low temperatures gain of the SiPMs can be high enough to resolve the single photoelectron peaks



**Example histograms from 8 SAE scintillators*

** uDAQ gives a digital output after shaping the pulses.*

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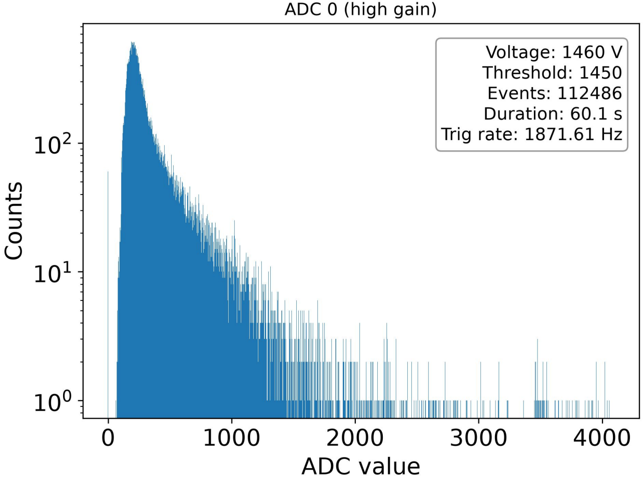
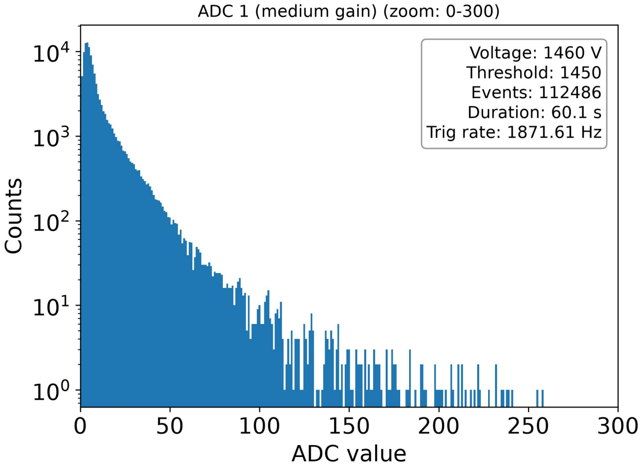
What do we see in the lab?

- The high gain channel resolution is not great
- The MIP peak distribution is completely masked by Dark Rate and low energy natural radioactivity background
- Both gains have pile up features that can further affect the dynamic range





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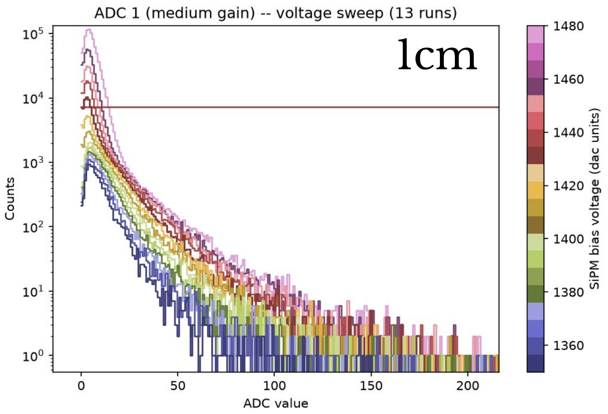
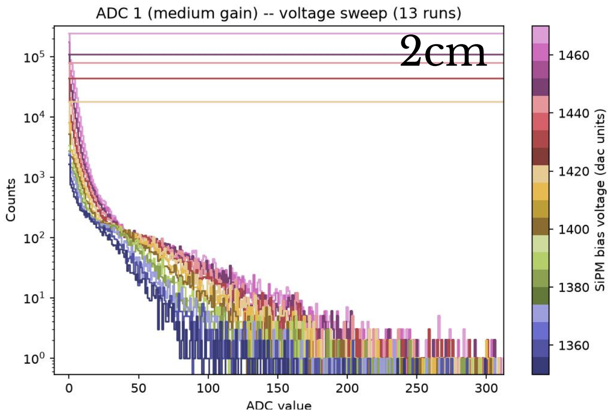
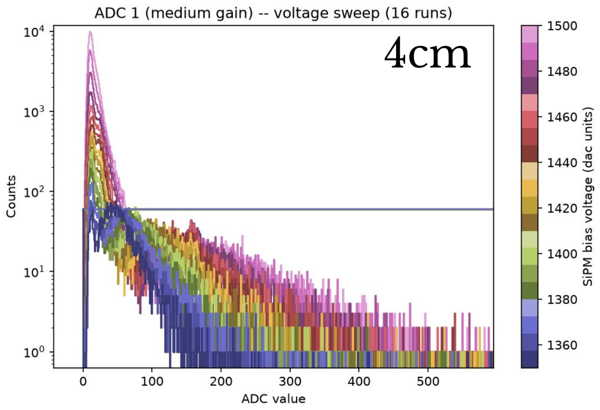
Can we see the MIP with increased thickness?

- Supplied Bias Voltage scans performed with 3 different thickness compositions
  - Increased thickness allows higher energy deposit.
  - The MIP distribution becomes more evident already at 2cm for significantly lower bias voltage
  - Higher voltage introduces higher dark rate noise
- Useful but very expensive, and therefore impractical to use higher thickness







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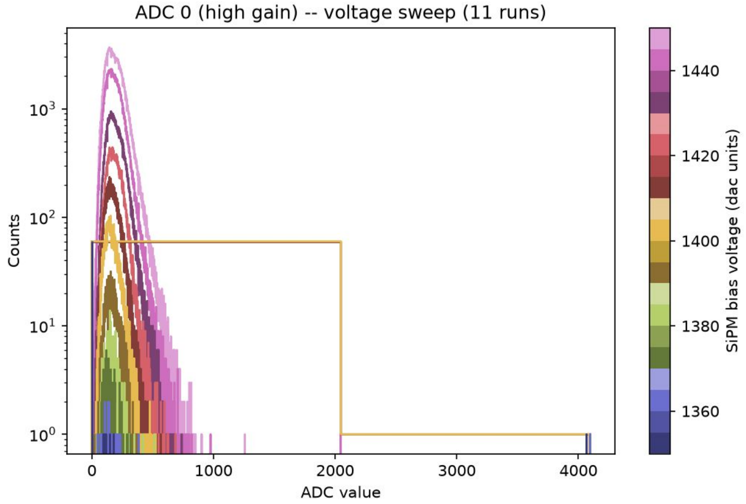
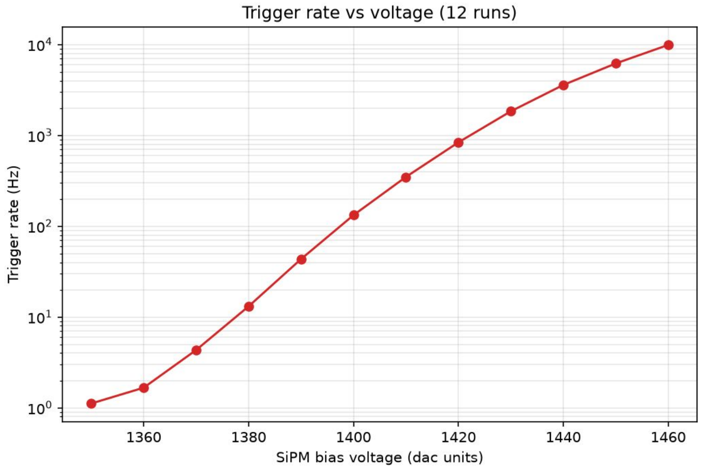
What does the SiPM see without scintillators

- Voltage scan with the same SiPM used previously, but without the incident fibre bundle
  - With 1cm thickness we are in the order 4 region
  - Lower temperatures will improve this picture





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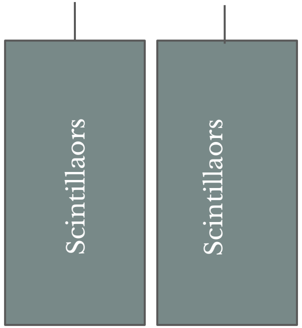
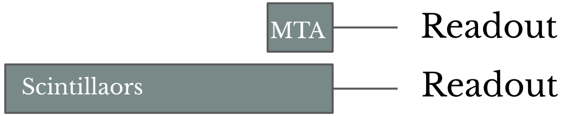
Coincidence Measurements

- Exploring coincidence measurements for calibration in 3 different configurations
  - Half length panels with 4 scintillation bars each used
  - Performed measurements in the lab as well as outside to account for overburden

Stacked (1)



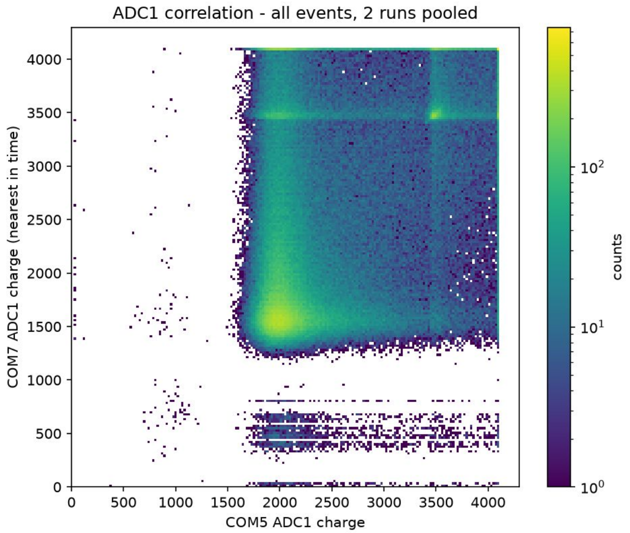
Sideways (2)

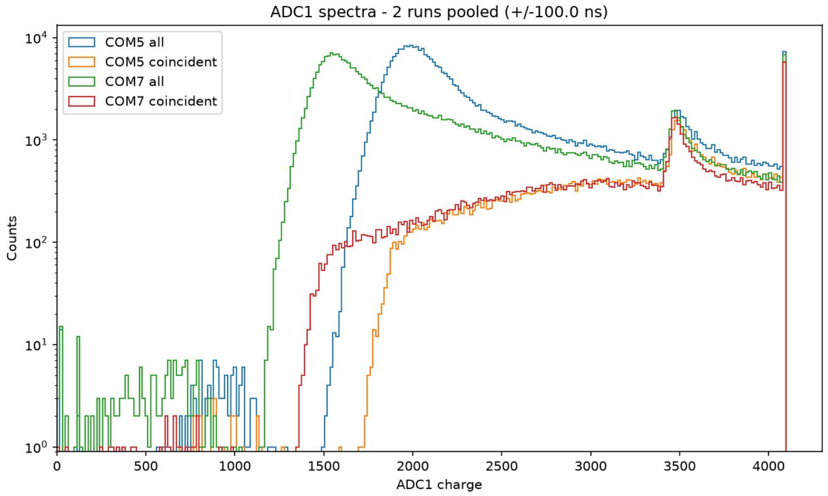


Stacked Hybrid (3)

Coincidence Measurements

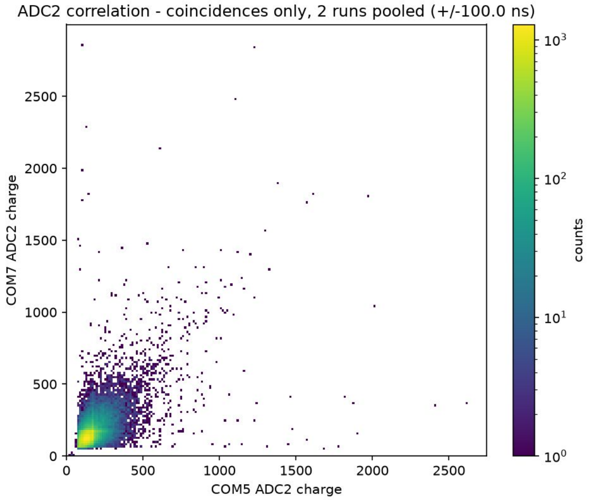
- Preliminary studies of the coincidence rate in the 3 configurations
- Config 1: Stacked on this slide. **Coincidence rate: ~22Hz**
  - High gain channel cannot resolve the MIPs
  - Pile up around 3500 ADCs

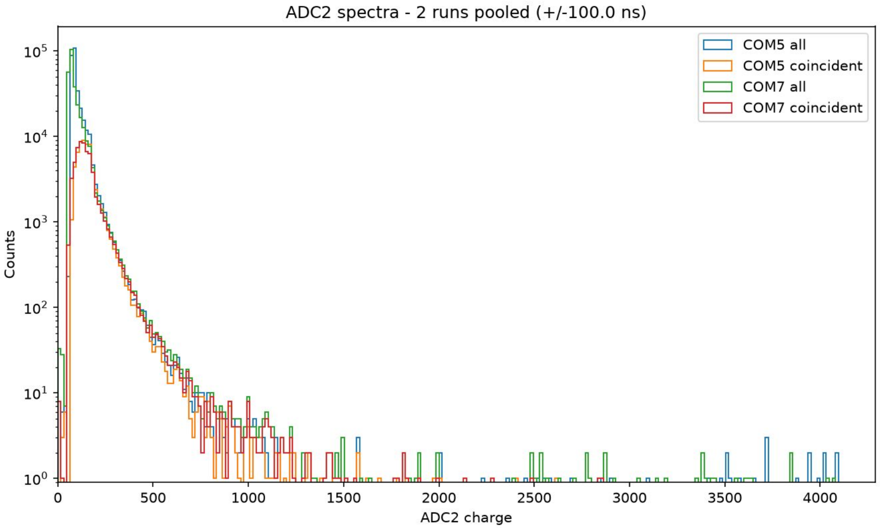




Coincidence Measurements

- Preliminary studies of the coincidence rate in the 3 configurations
- Config 1: Stacked on this slide
  - Medium gain allows a look into the MIP peak





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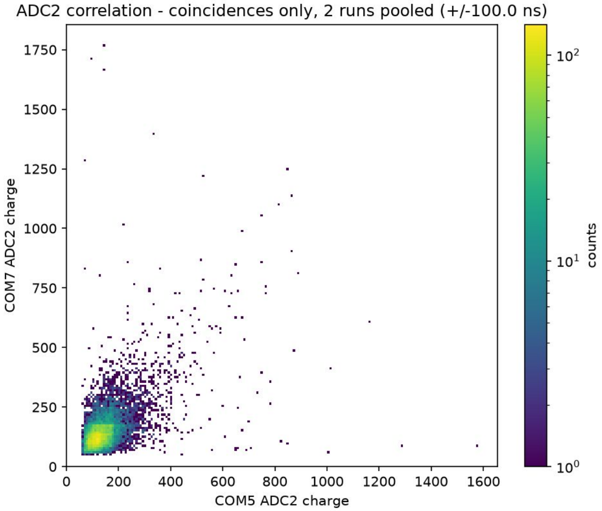
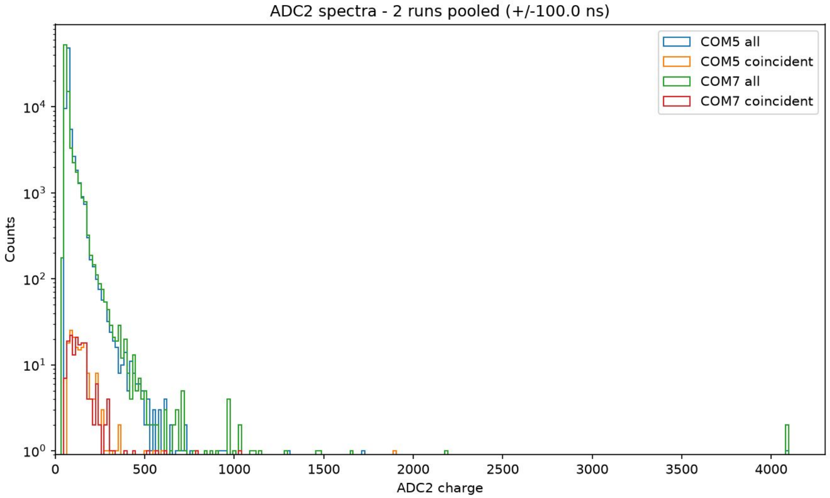
Coincidence Measurements

- Configuration 2: Side by side :**Coincidence rate: ~0.7Hz**
  - Allows us to cover more effective area, and useful for detector response studies
  - Rate should improve with size and lower temperature





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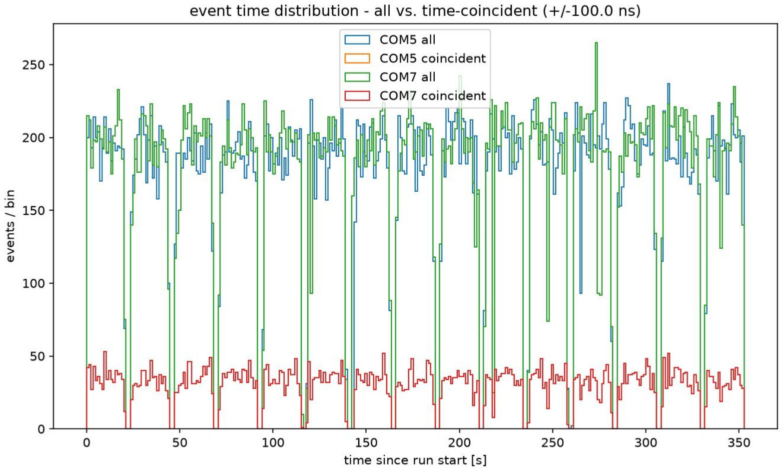
Summarized Rates

- There is clearly an improvement in the number of MIPs detectable without the overburden
- The rate in sideways coincides is limited by its size
- The rates are also however limited by the electronics:
  - Buffer flushing highly time expensive (~3s deadtime), needed every 4-6s for lower thresholds

Configuration	Rate
Stacked (lab)	22.41 Hz
Side-by-side (lab)	0.79 Hz
Stacked with MTA (lab)	0.71 Hz
Stacked (outdoors)	25.67 Hz
Side-by-side (outdoors)	0.69 Hz



Takeaways and Outlook

- The measurements with the complete prototype are challenging but we are making progress :)
- Calibration can potentially be achieved with optimal effective area in the 2nd configuration as well as the tagger combination with longer calibration runs (~20mins).
- SiPM dark rates need to be studied more extensively, preferably in a temperature range
- Setup a SiPM calibration test bench
- uDAQ limitations need to be addressed, firmware and hardware
  - Dedicated work will start soon in the Hawaii group

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BACKUP SLIDES

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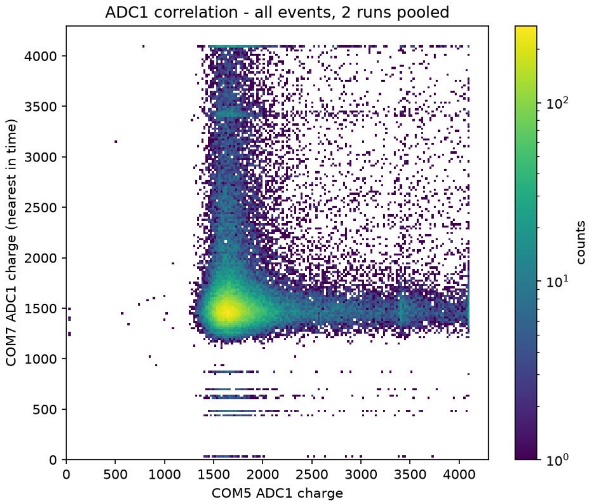
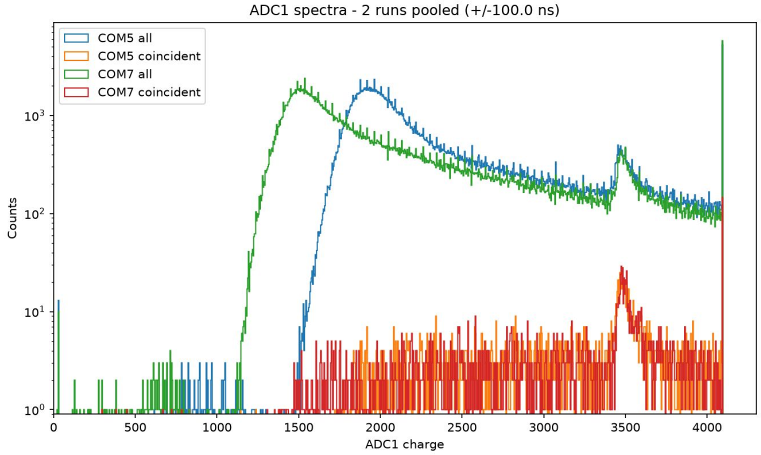
Coinc measurements in side-ways config





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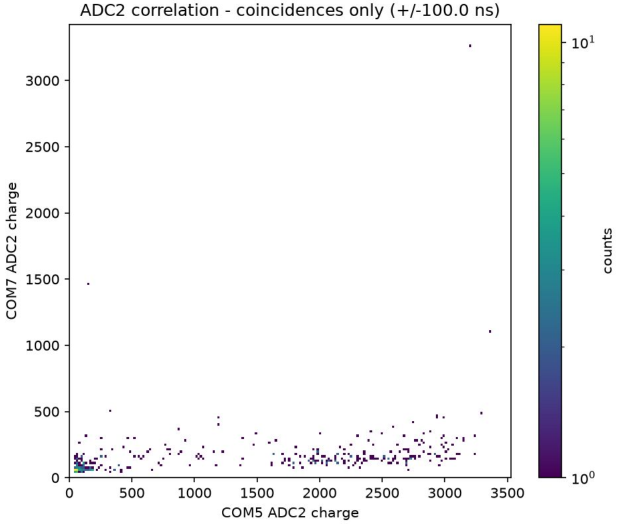
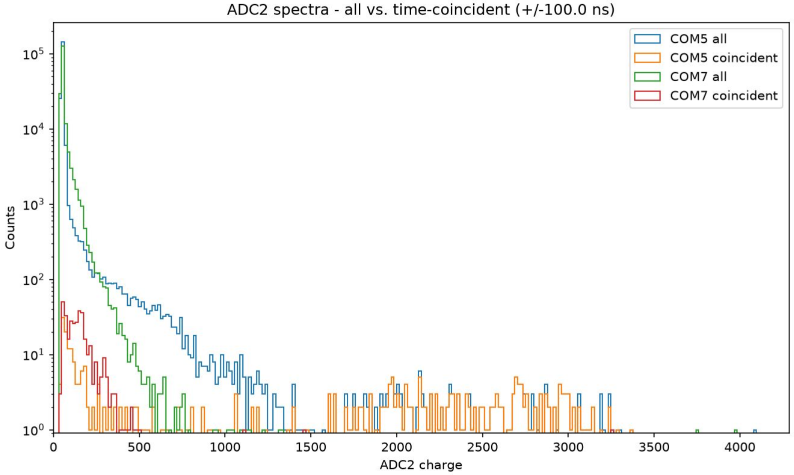
Coinc measurements with MTA





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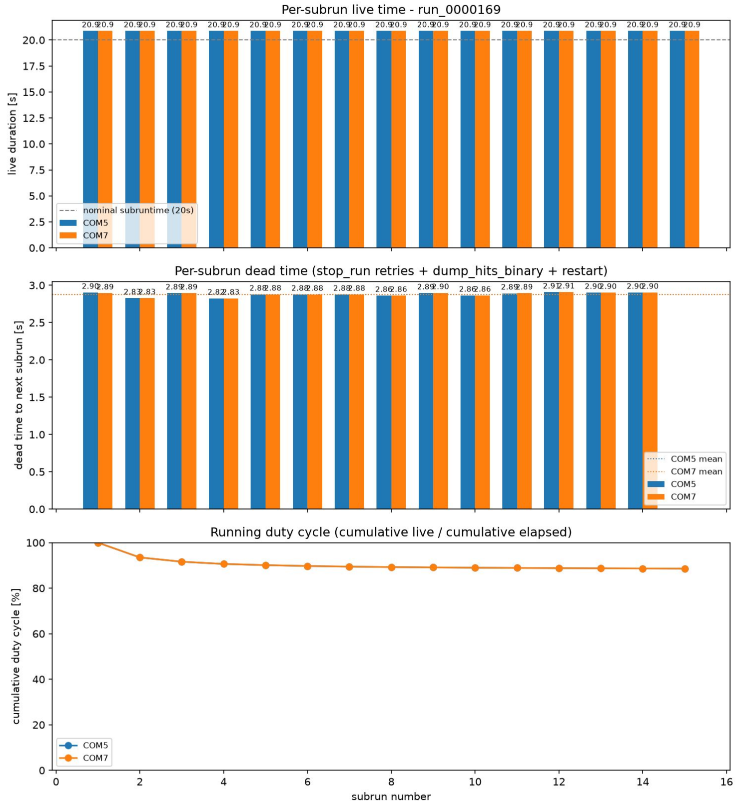
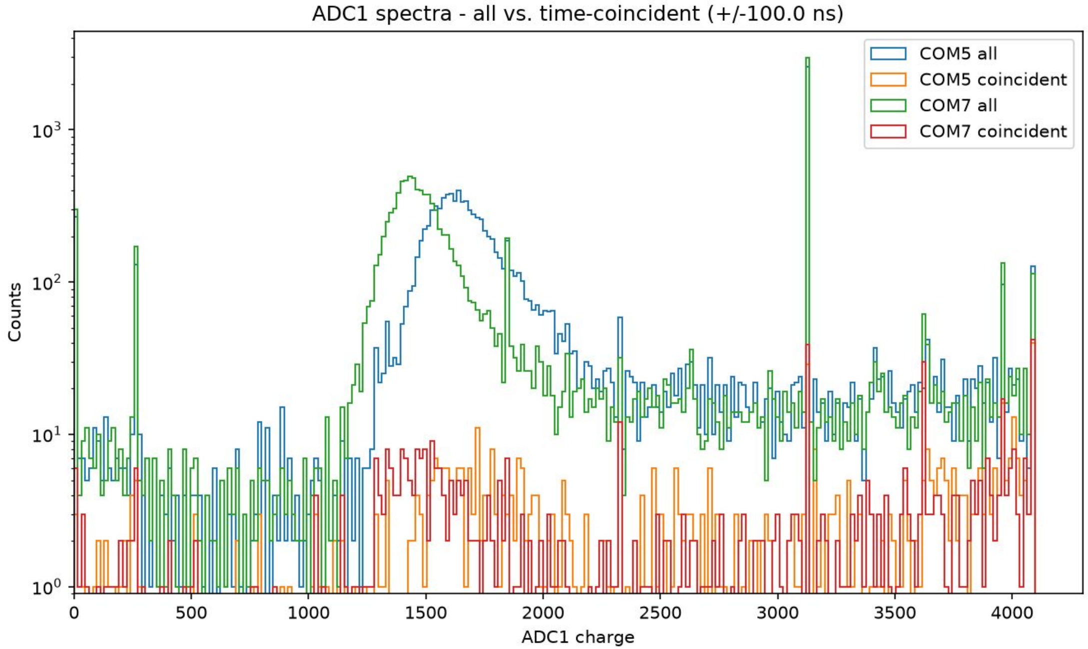
Some deadtime/Runtime stats



Timing related issues in the hitbuffer output



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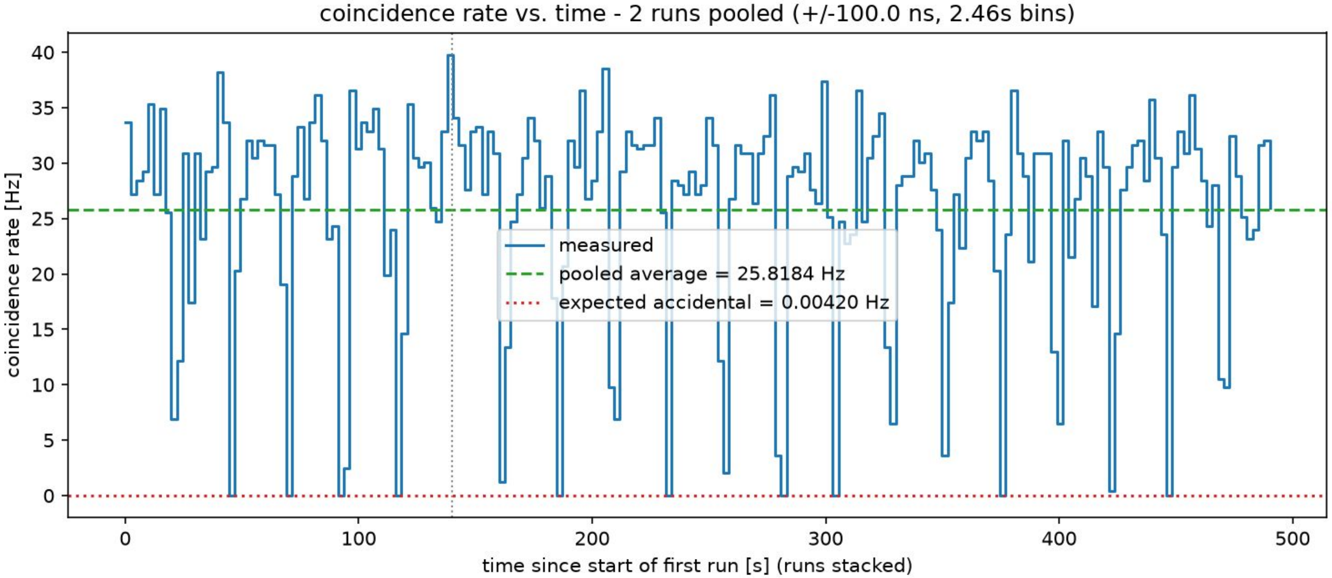
Average coincidence rates



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