

Towards an online MIP calibration

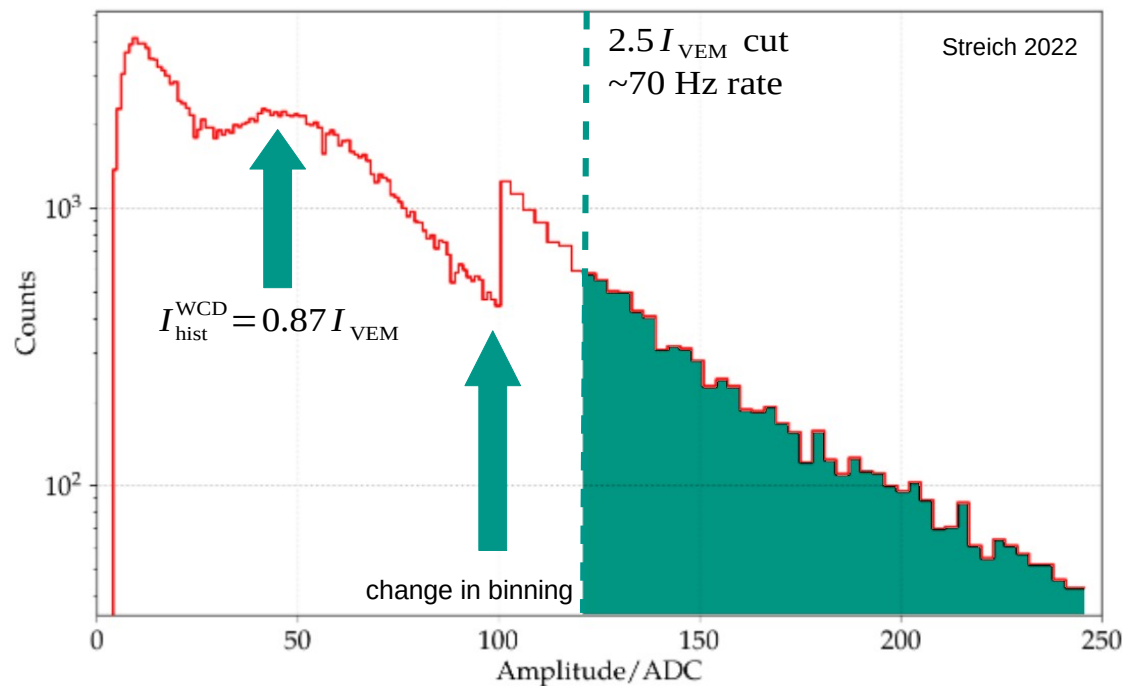
Paul Filip*, David Schmidt

Outline

- Overview of current (WCD) online calibration
- Rate/Threshold relationship from T3 histos
- Caveat: `muonBuffer` and `showerBuffer`
- Expected performance with T1-preselection
- Summary and outlook

Current (WCD) calibration

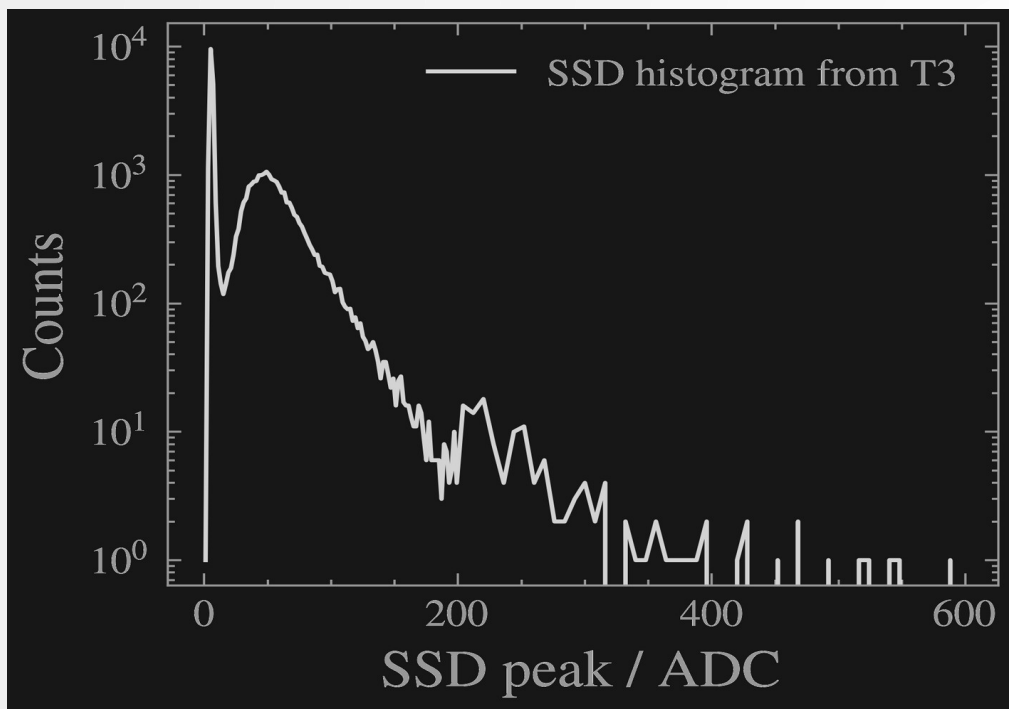
- WCD offline calibration
 - Fit muon hump in histogram



- WCD online calibration
 - Calibration trigger with threshold , that satisfies:
 - Threefold coinc. of $0.7 k$
 - >1 PMT above $1.0 k$
 - Iteratively adjust threshold until 70 Hz rate is reached
 - Threshold equals $k \approx 2.5 I_{VEM}$
 - Accurate to $\sim 2\%$
 - See also GAP2023-049

Setting up rate/threshold relationship

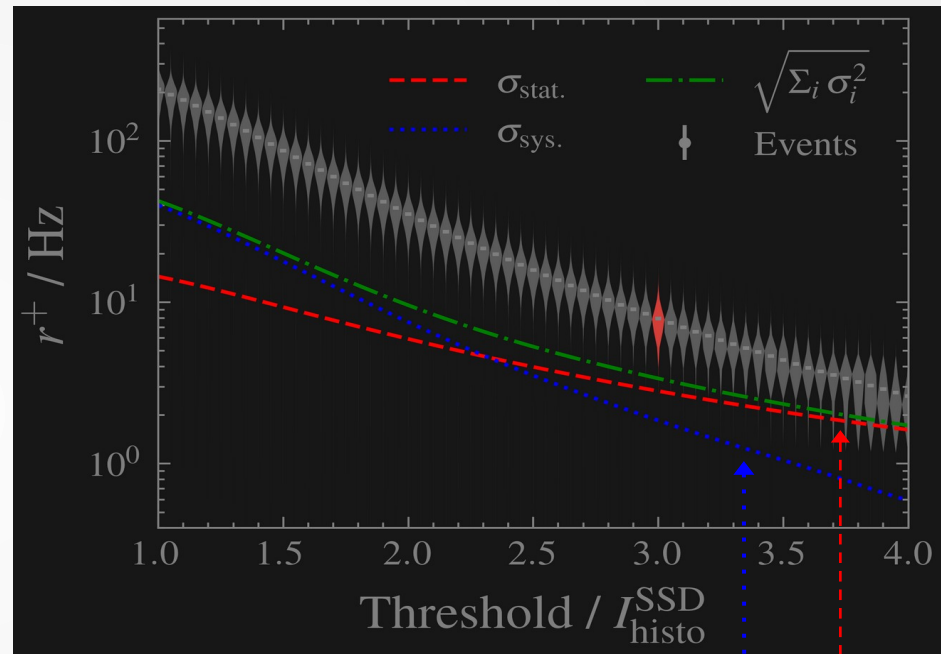
- 870,000 SSD histograms from SD-1500 T3s in Jun/Dec 2023
- Bootstrap muon events according to histo to estimate $I_{\text{histo}}^{\text{SSD}}$



- Characteristic shape
- Scale differs due to gain
- I_{MIP} determined by:
 - Weather
 - Electronics
 - ???
- Does there exist a stable rate/threshold relationship?

MIP → Rate

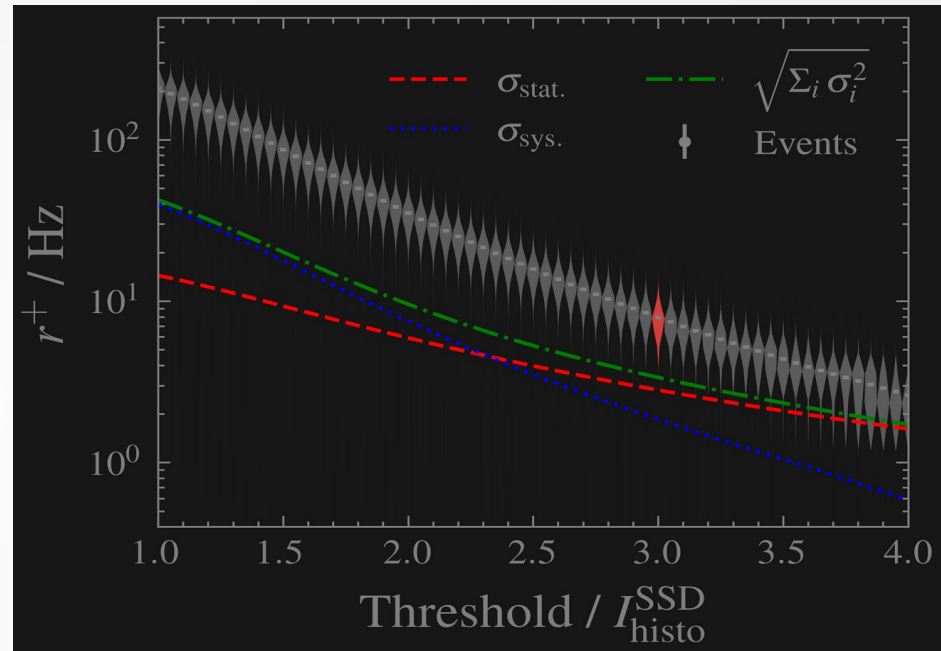
- Fit parabola to histogram to obtain “true” $I_{\text{histo}}^{\text{SSD}}$
- For threshold t in $\{1.0, \dots, 5.0\} I_{\text{histo}}^{\text{SSD}}$:
 - Count histo entries above t
 - Per station: remove outliers at 3σ
 - Per station: take mean of samples
 - Divide by histogram acquisition time (61s)
 - Average across all stations



- Systematic: station-to-station fluctuations $\sim 20\%$
- Statistical: Poisson error on counts above threshold

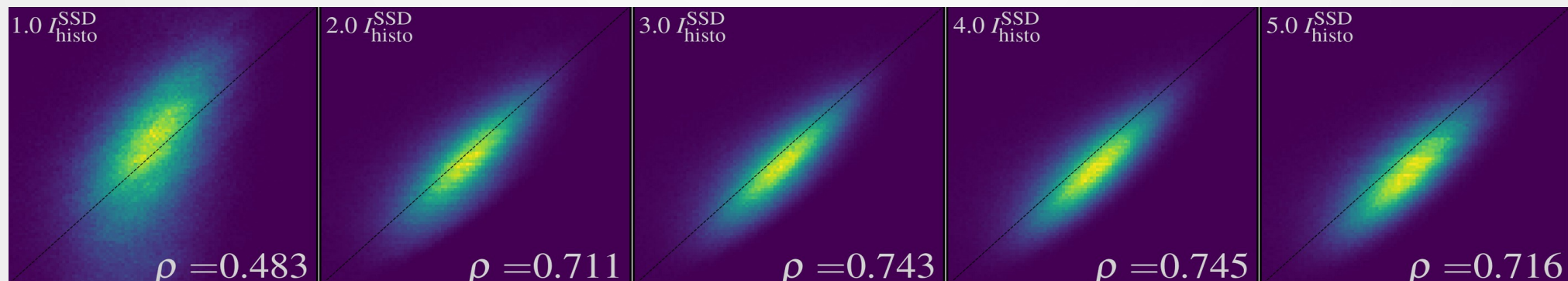
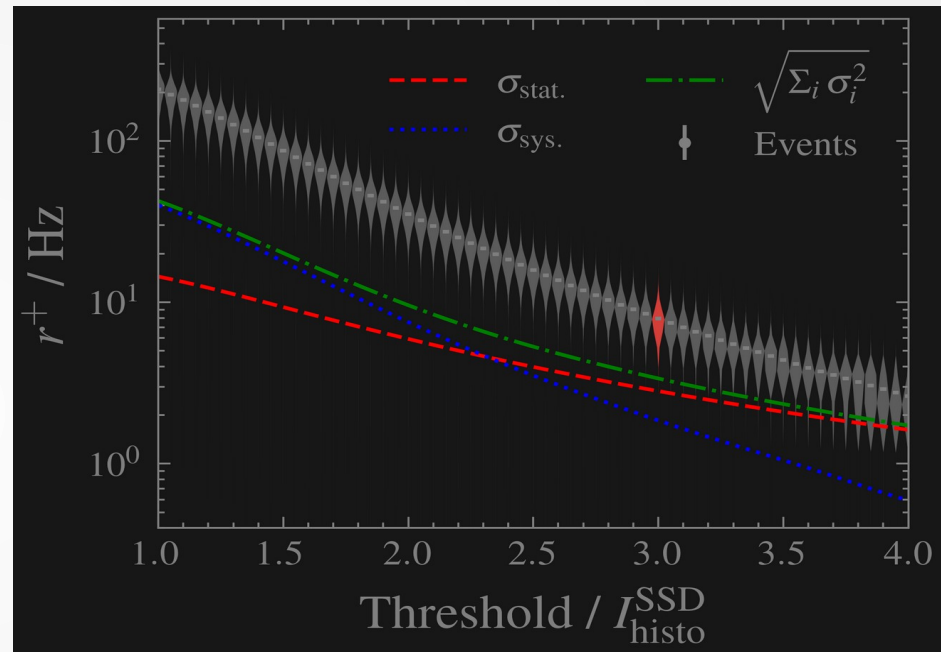
MIP \leftarrow Rate

- Adjust threshold [ADC] of SB trigger until rate converges to 1000 Hz
- $r_{\text{rate}}^{\text{SSD}}$ given as $r_{\text{rate}}^{\text{SSD}}$ (read off $r_{\text{rate}}^{\text{SSD}}$ from plot)
- Compare $r_{\text{rate}}^{\text{SSD}}$ and “true” $r_{\text{histo}}^{\text{SSD}}$

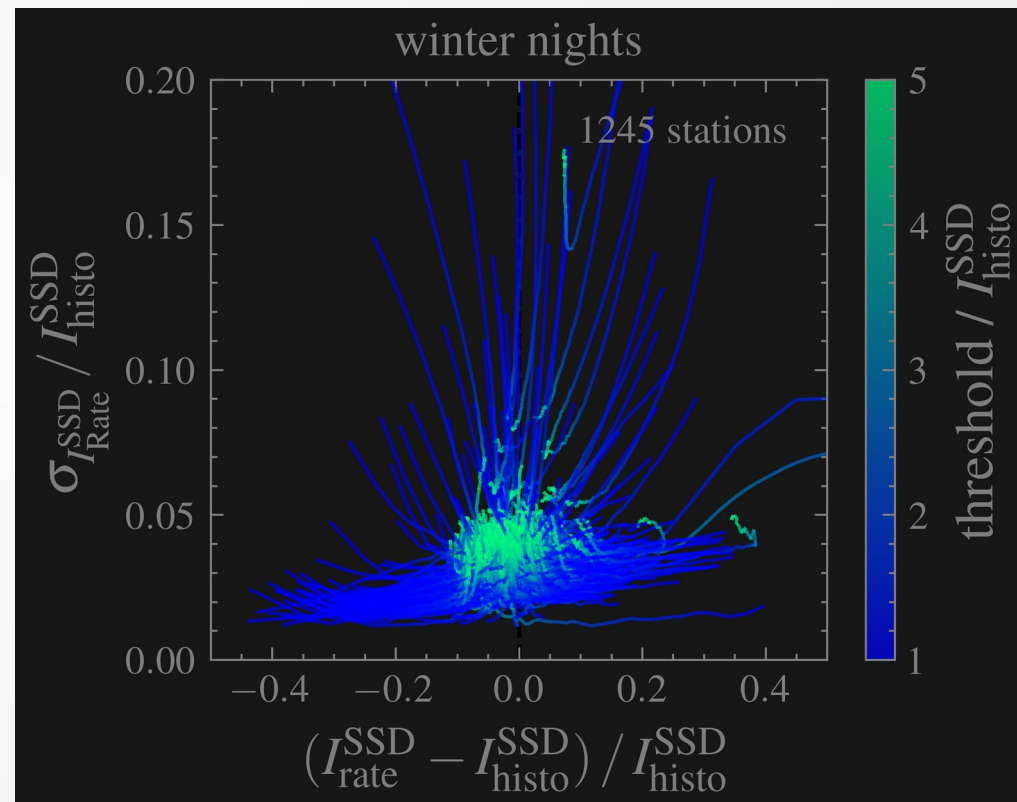
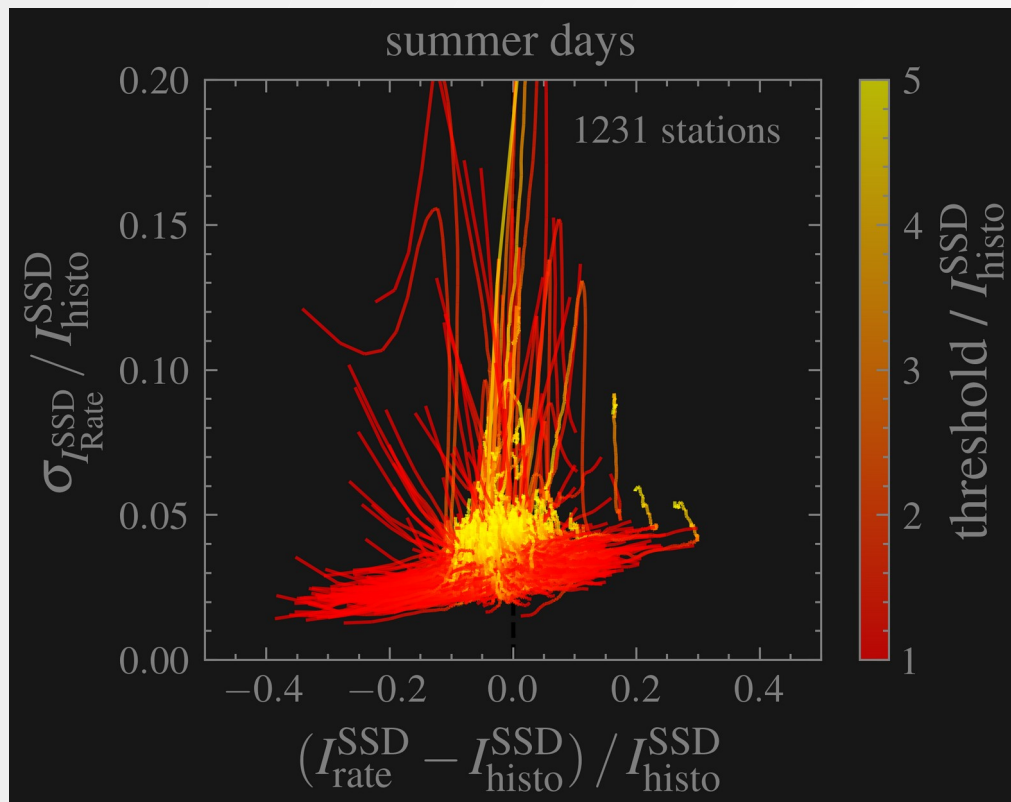


MIP ← Rate

- Adjust threshold t [ADC] of SB trigger until rate converges to f Hz
- $I_{\text{rate}}^{\text{SSD}}$ given as kt (read off k, f from plot)
- Compare $I_{\text{rate}}^{\text{SSD}}$ and “true” $I_{\text{histo}}^{\text{SSD}}$
- Strong EM influence at low thresholds
- Best correlation at intermediate values
- Larger sampling error at very high thresholds

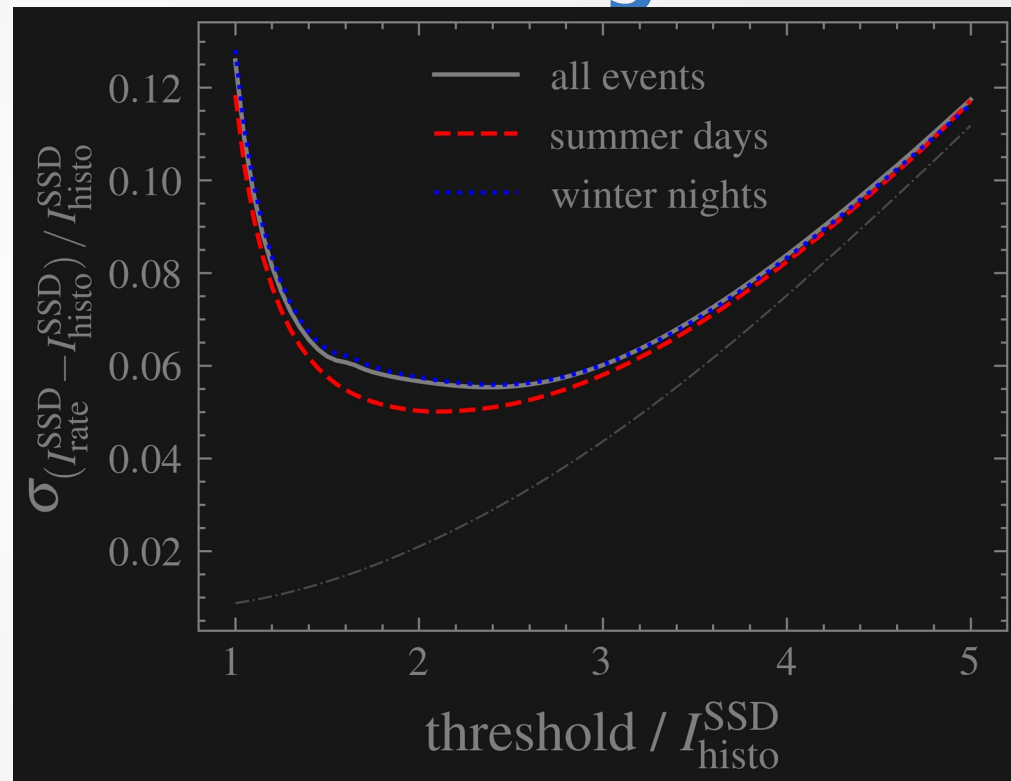
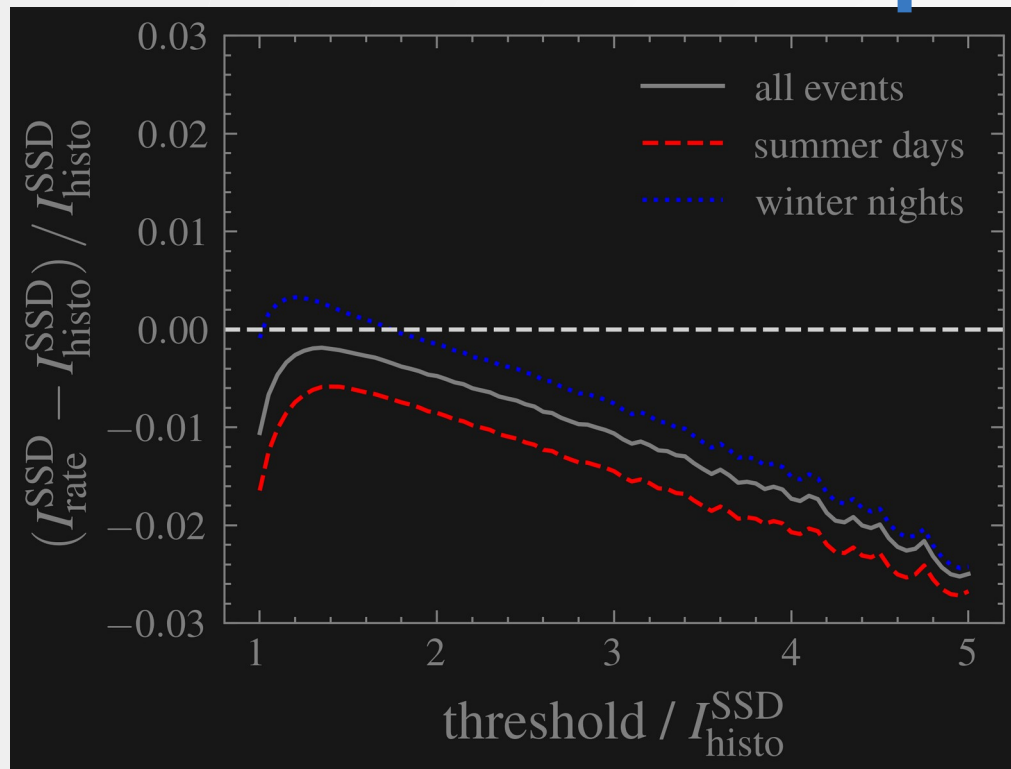


MIP ← Rate



- Similar behaviour across large projected temperature ranges

Performance of simple rate-based algorithm



- Small bias ($<3\%$) for all considered thresholds
- Error of $\sim 6\%$ for selected rate/threshold relationships

Caveat: T1 preselection

- Rate/threshold relationships derived from muonBuffer events
 - Require >30 ADC above baseline (uncalibrated, >500 Hz)
- Online calibration performed on showerBuffer events
 - Require WCD-T1 (e.g. threefold coinc. of $>1.75 I_{\text{rate}}^{\text{WCD}}$, ~ 100 Hz)
- Much easier implementation of SSD online calibration if it works on T1-preselected traces \rightarrow but lower rate! Higher error!

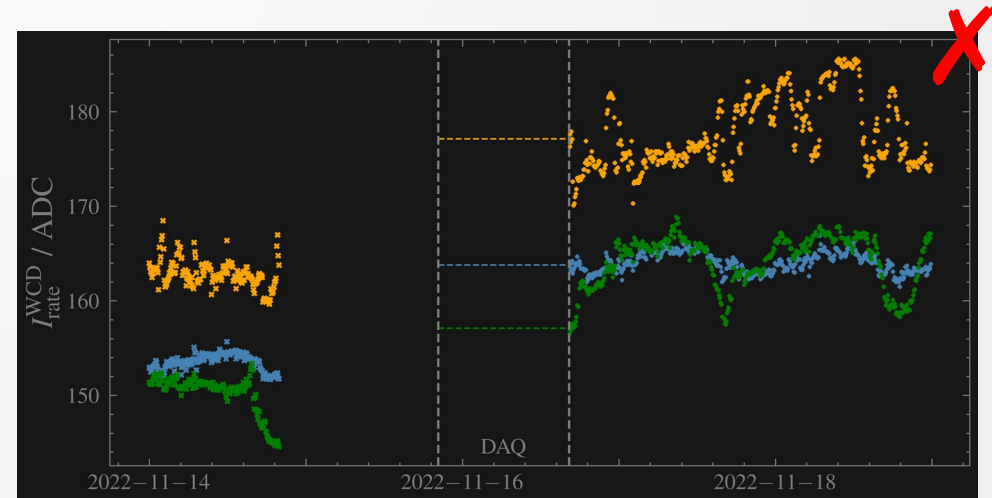
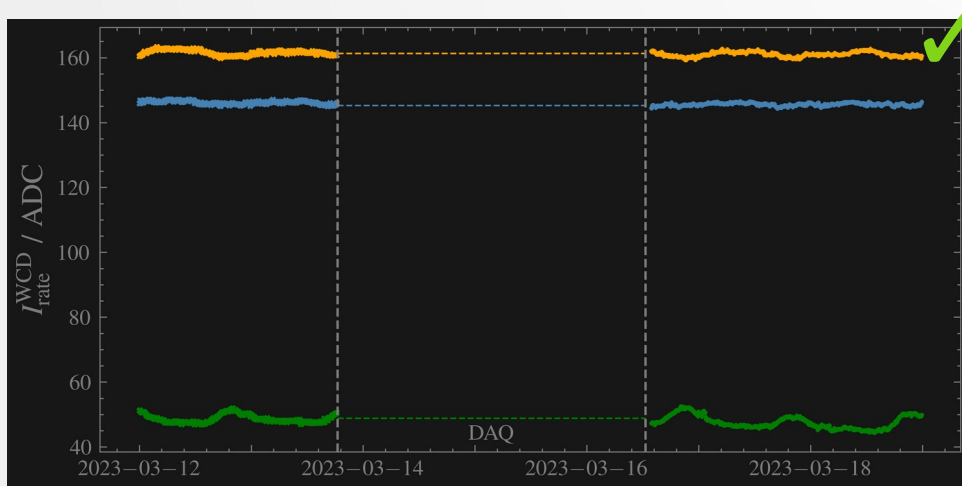
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estimate from UUB randoms

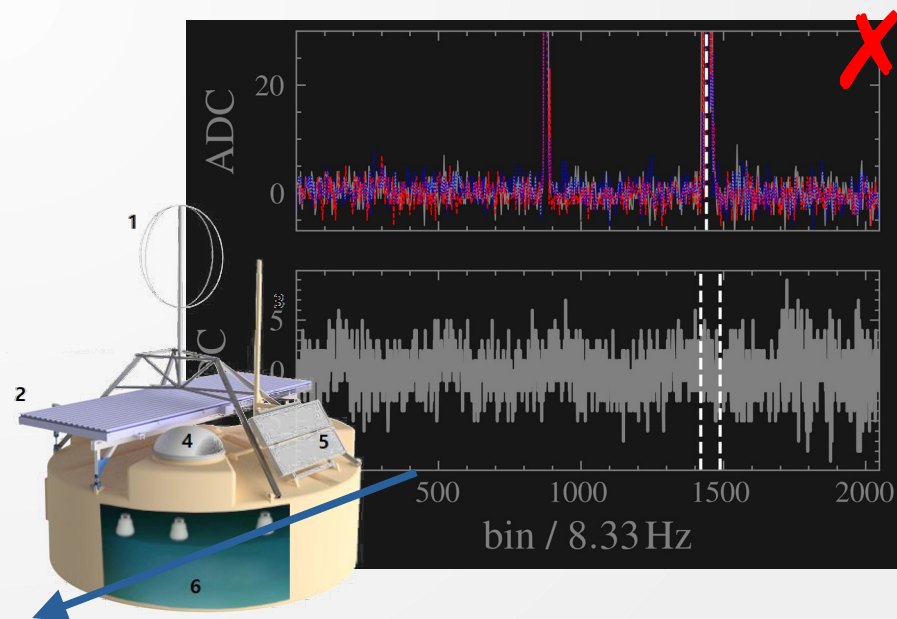
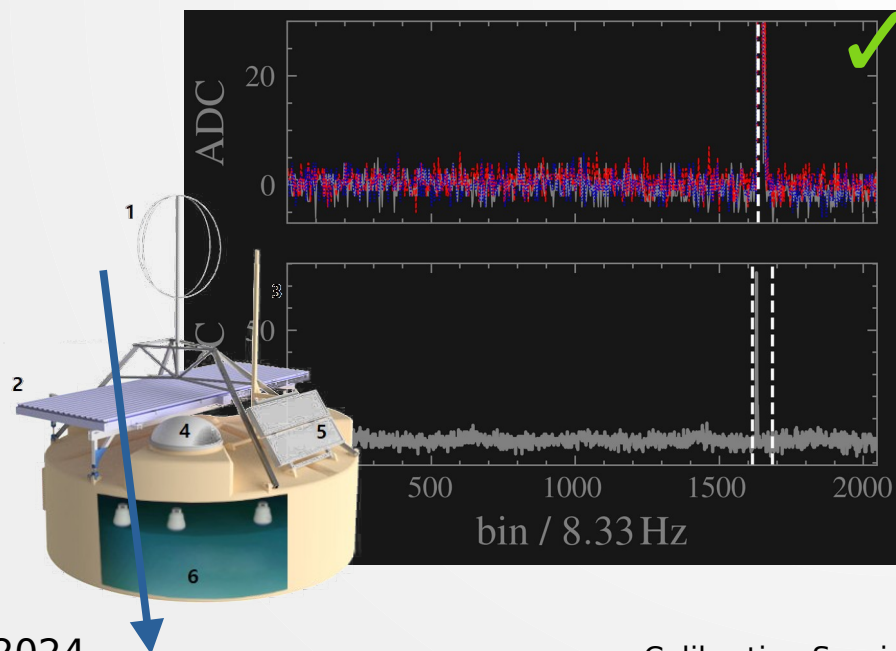
Caveat: T1 preselection

- Build SSD pulse height histogram for stations that have:
 - Online calibration functioning for all 3 PMTs 10/12 stations
 - Fluctuations of $I_{\text{rate}}^{\text{WCD}}$ before/after DAQ <5% 8/12 stations
 - Jump in $I_{\text{rate}}^{\text{WCD}}$ before after DAQ <10% 4/12 stations



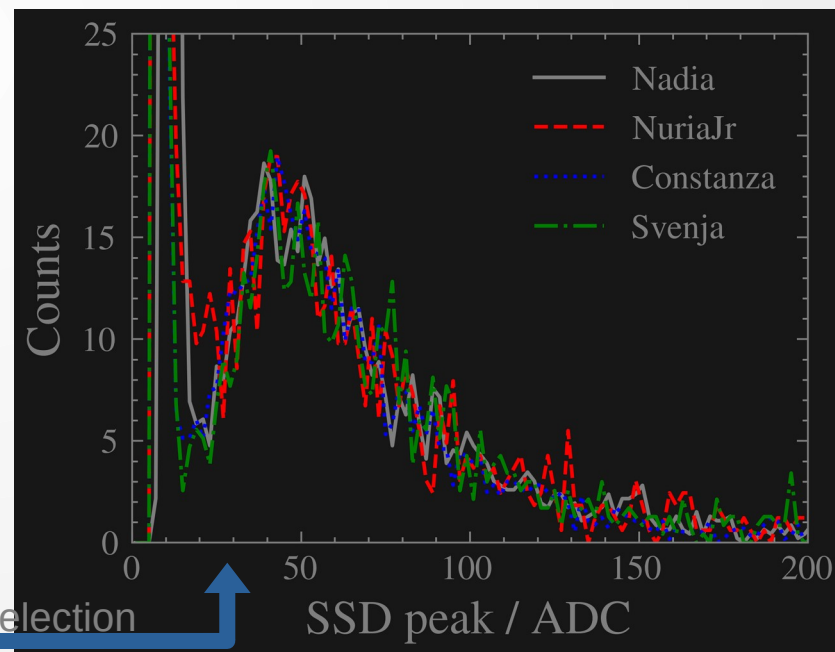
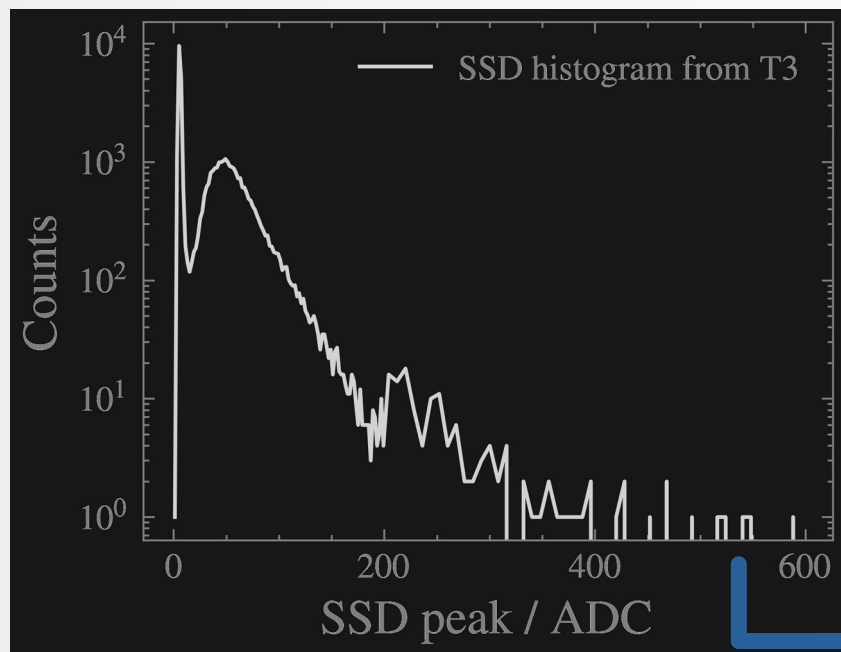
Caveat: T1 preselection

- Build SSD pulse height histogram from events that have:
 - T1 trigger in WCD trace ~ 100 Hz
 - Coincident SSD signal with T1 latch bin $\sim 1-2\%$?



T1 preselection: statistical error

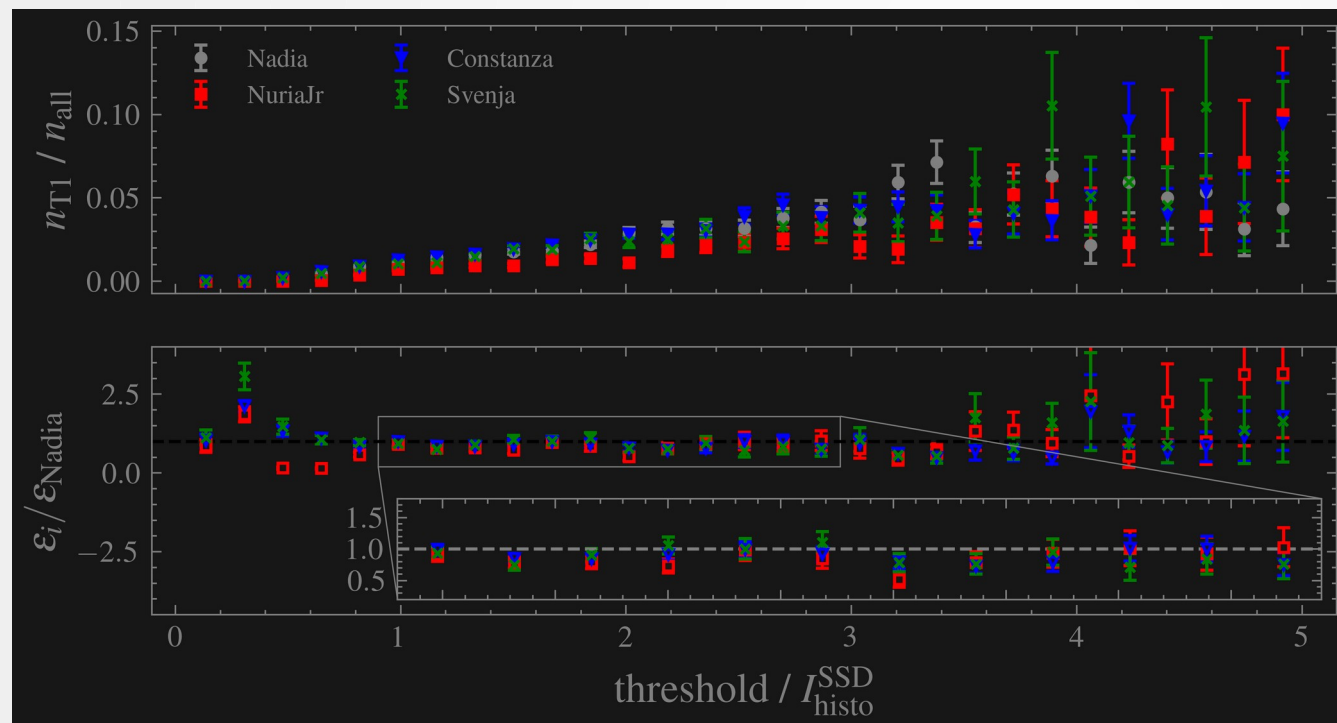
- Rate drops by factor ~ 100 , associated Poissonian error becomes 5% ($\sim 1.5\%$ before), not great, not terrible...



T1 preselection

T1 preselection: systematic error

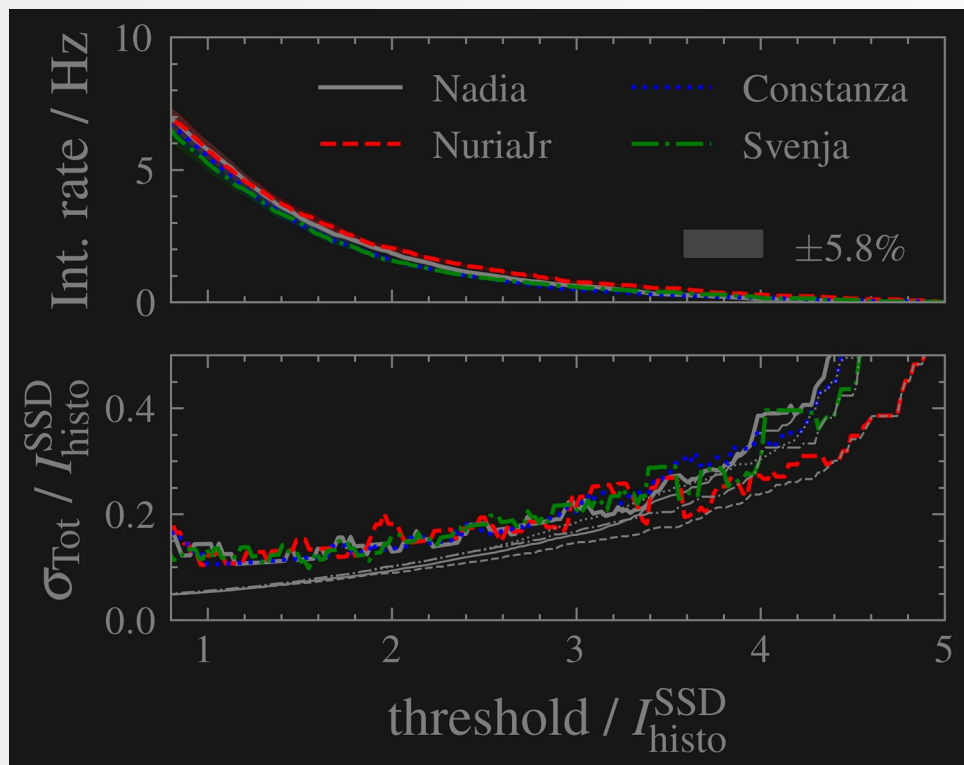
- Compare station-to-station fluctuations in T1 probability
- Analyze spread in region that showed minimal error



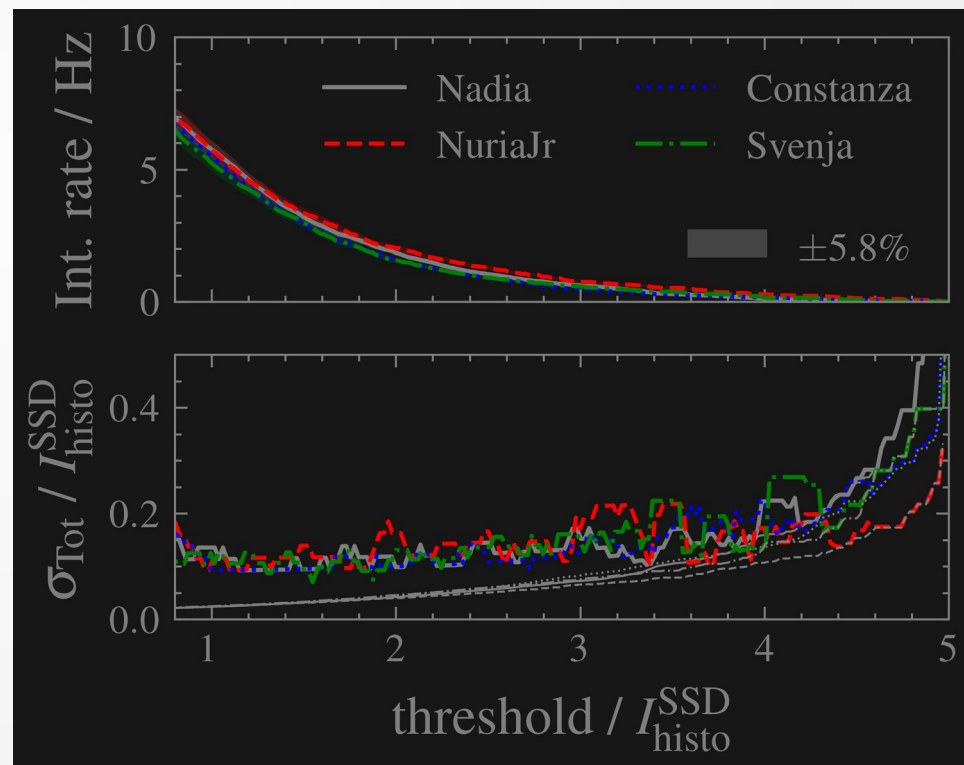
- ~10% fluctuation in RoI
- In line with expectations from T3 histograms
- Larger contribution to error on $I_{\text{rate}}^{\text{SSD}}$ due to shallower rate profile!

T1 preselection: expected total error

DAQ time 61s



DAQ time 300s



Summary and outlook

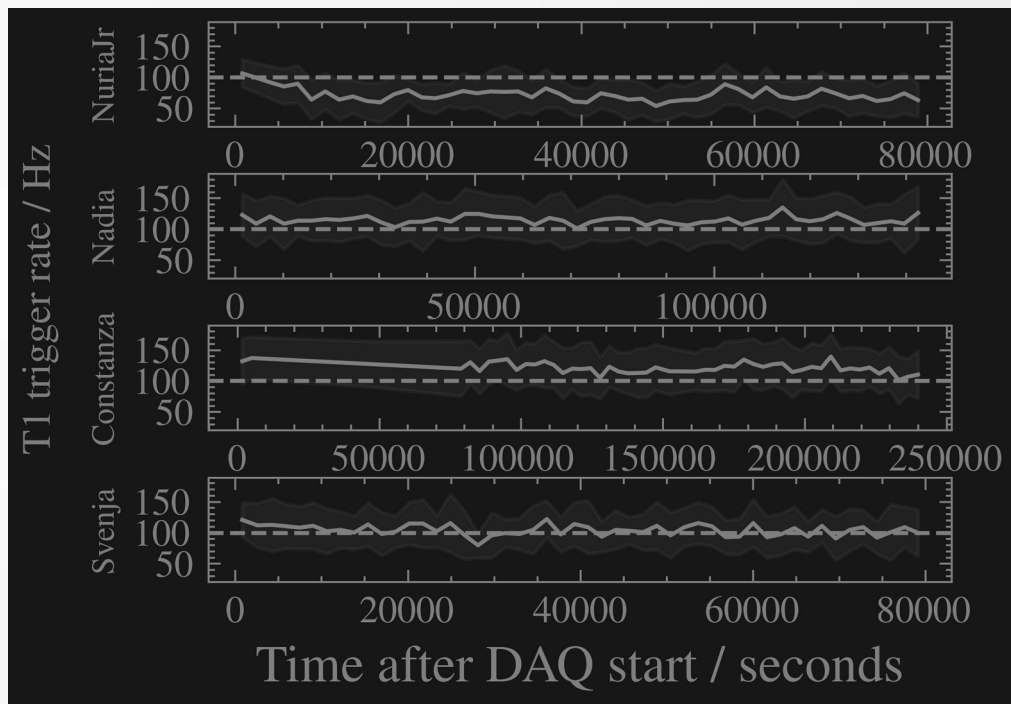
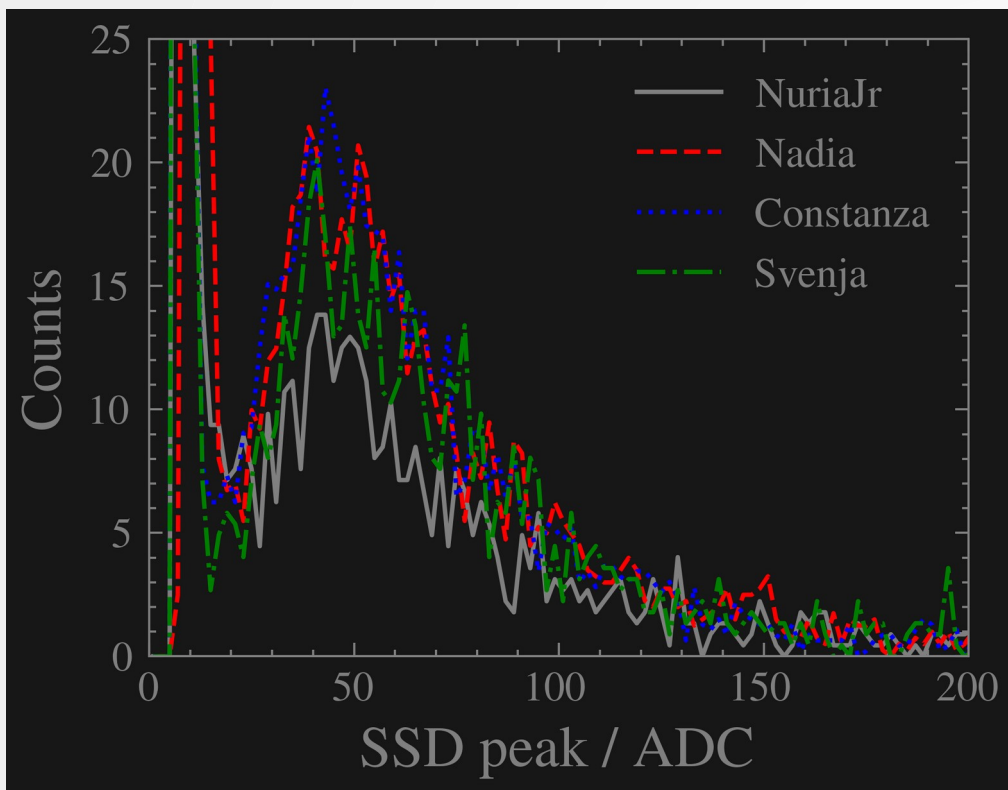
- Rate based algorithm for SSD online calibration shows small bias and acceptable precision for muonBuffer events
- T1-preselection simplifies implementation in station software
- Stricter selection criteria increase total error: $\sim 10\%$
- Remains to be seen if presented method is precise enough
 - For monitoring: yes
 - For triggers: unsure
- Next step: first tests with dedicated stations

BACKUP

Possible implementation strategies

Method	(+)	(-)	error
Rate-based w/ T1-preselection	Easy implementation	Large error	>10%
Rate-based w/o T1-preselection	Small error	Requires refactoring of local station software	>5%
Fitting histogram at station level	Small error	No redundancy in case fitting strategy fails	~2%
WCD independent means of estimation	Independent of WCD	Likely large fluctuations	???

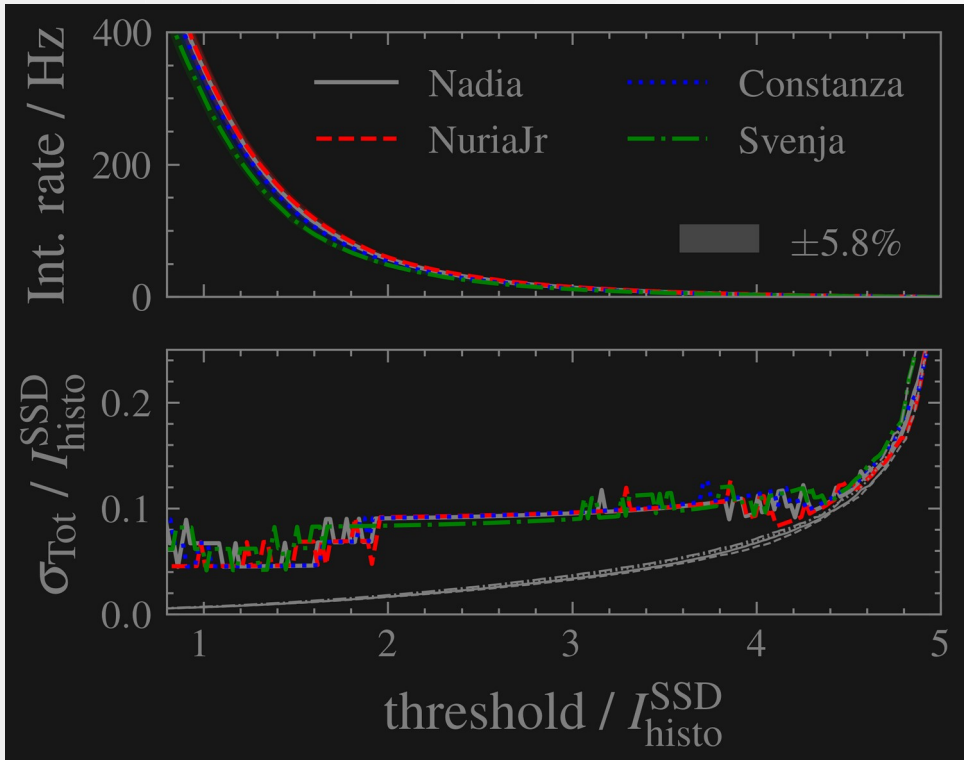
Uub randoms rate correction



- Normalize counts by factor $\text{mean_rate} / 100 \text{ Hz}$

No T1 preselection: expected total error

DAQ time 61s



DAQ time 300s

