Towards an online MIP calibration

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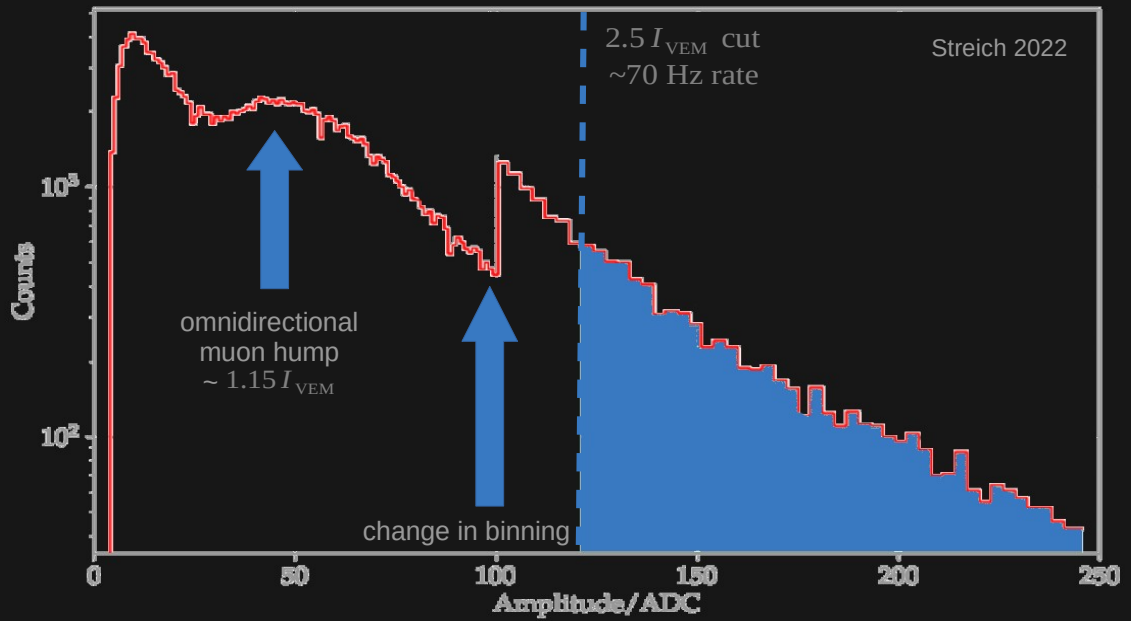
Outline

- 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

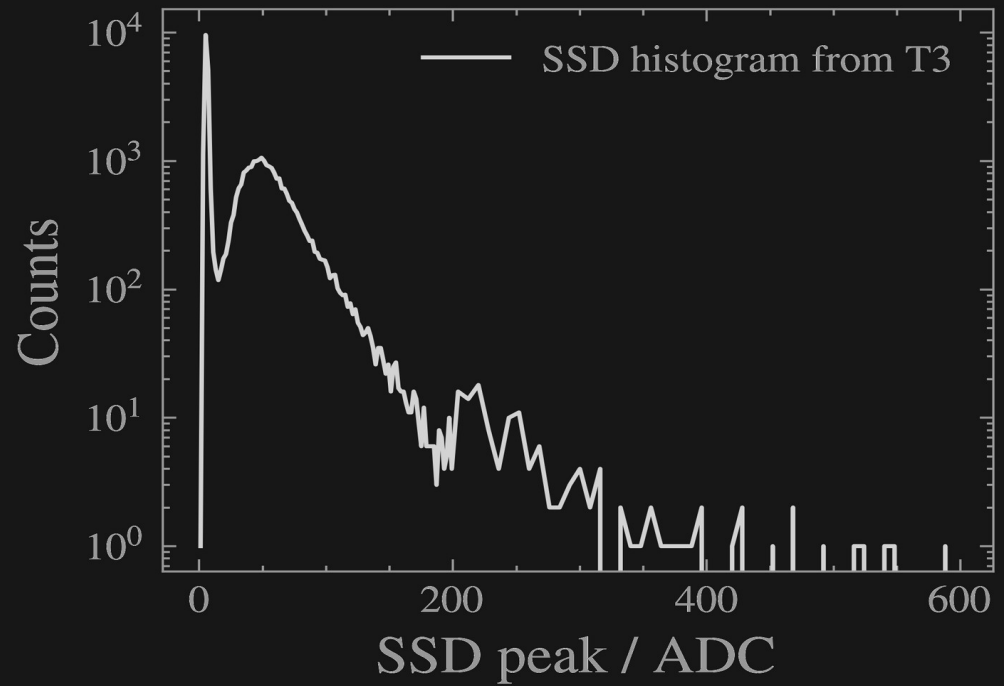
- WCD offline calibration
  - Fit muon hump in histogram



- WCD online calibration
  - Calibration trigger with threshold k, 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 $k \approx 2.5\,I_{\mathrm{VEM}}$
  - Accurate to ~2%
  - See alsp GAP2023-049

Setting up rate/threshold relationship

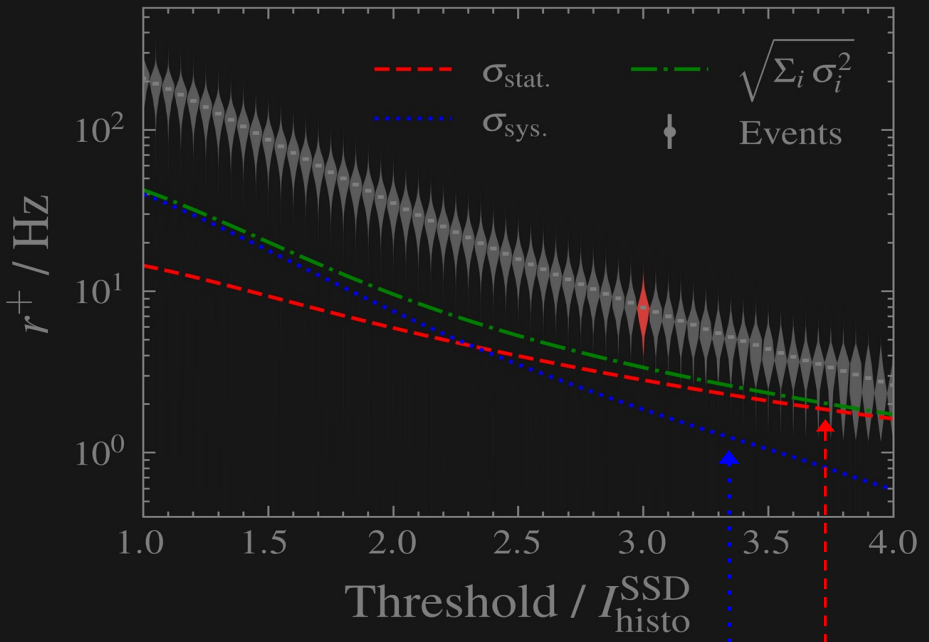
- 870,000 SSD histograms from SD-1500 T3s in Jun/Dec 2023
- Bootstrap muon events according to histo to estimate $I^{\mathrm{SSD}}_{\mathrm{histo}}$



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

MIP → Rate

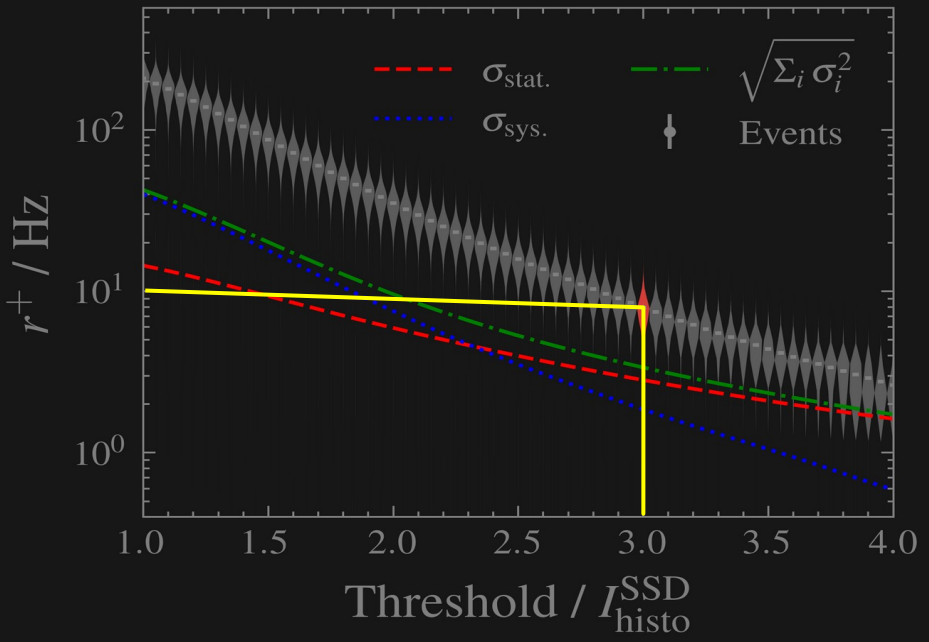
- Fit parabola to histogram to obtain "true" $I^{\mathrm{SSD}}_{\mathrm{histo}}$
- For threshold t in {1.0, ..., 5.0} $I^{\mathrm{SSD}}_{\mathrm{histo}}$:
  - Count histo entries above t
  - Per station: remove outliers at 3σ
  - Per station: take mean of samples
  - Divide by histogram acquisition time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



- Systematic: station-to-station fluctuations ~20%
- Statistical: Poisson error on counts above threshold

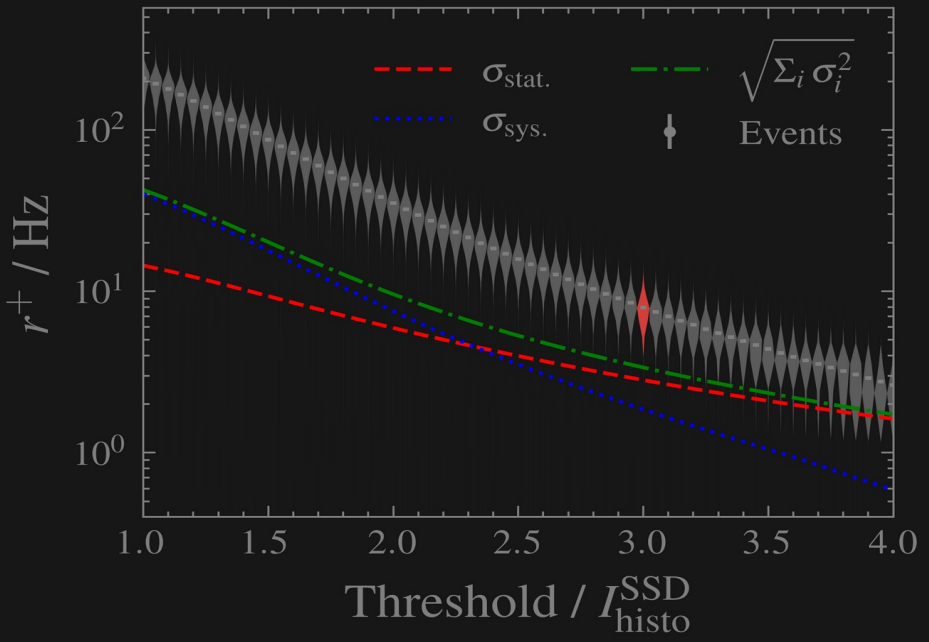
MIP ← Rate

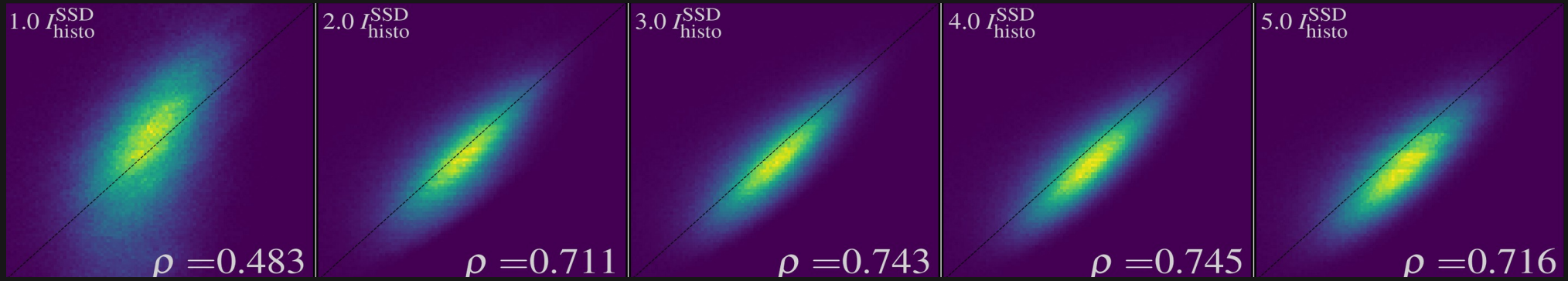
- Adjust threshold t [ADC] of SB trigger until rate converges to f Hz
- $I^{\mathrm{SSD}}_{\mathrm{rate}}$ given as kt (read off k,f from plot)
- Compare $I^{\mathrm{SSD}}_{\mathrm{rate}}$ and "true" $I^{\mathrm{SSD}}_{\mathrm{histo}}$



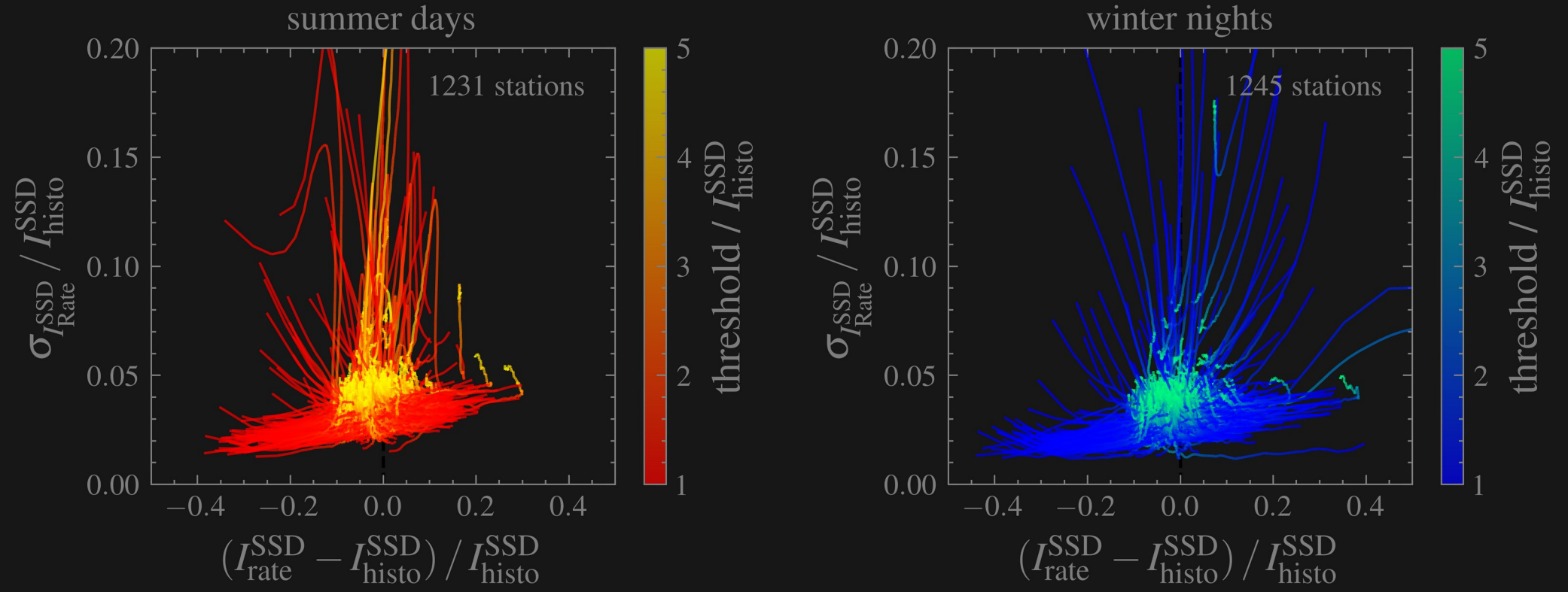
MIP ← Rate

- Adjust threshold t [ADC] of SB trigger until rate converges to f Hz
- $9999999\, I^{\mathrm{SSD}}_{\mathrm{rate}}$ given as kt (read off k,f from plot)
- Compare $I^{\mathrm{SSD}}_{\mathrm{rate}}$ and "true" $I^{\mathrm{SSD}}_{\mathrm{histo}}$
- Strong EM influence at low thresholds
- Best correlation at intermediate values
- Larger sampling error at very high thresholds



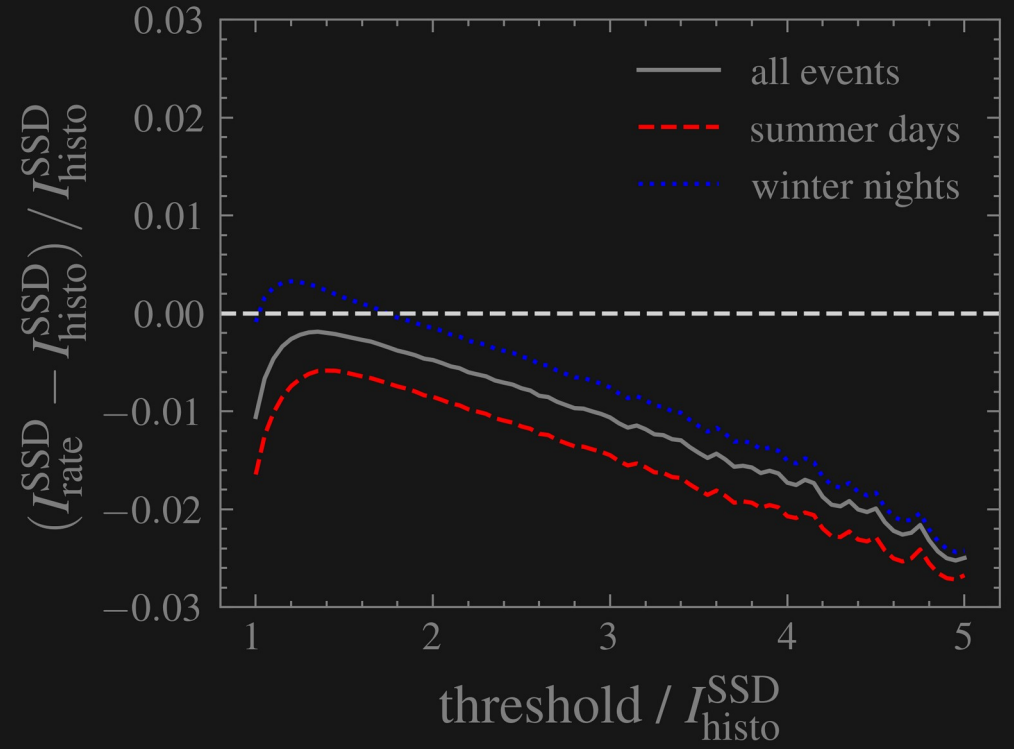


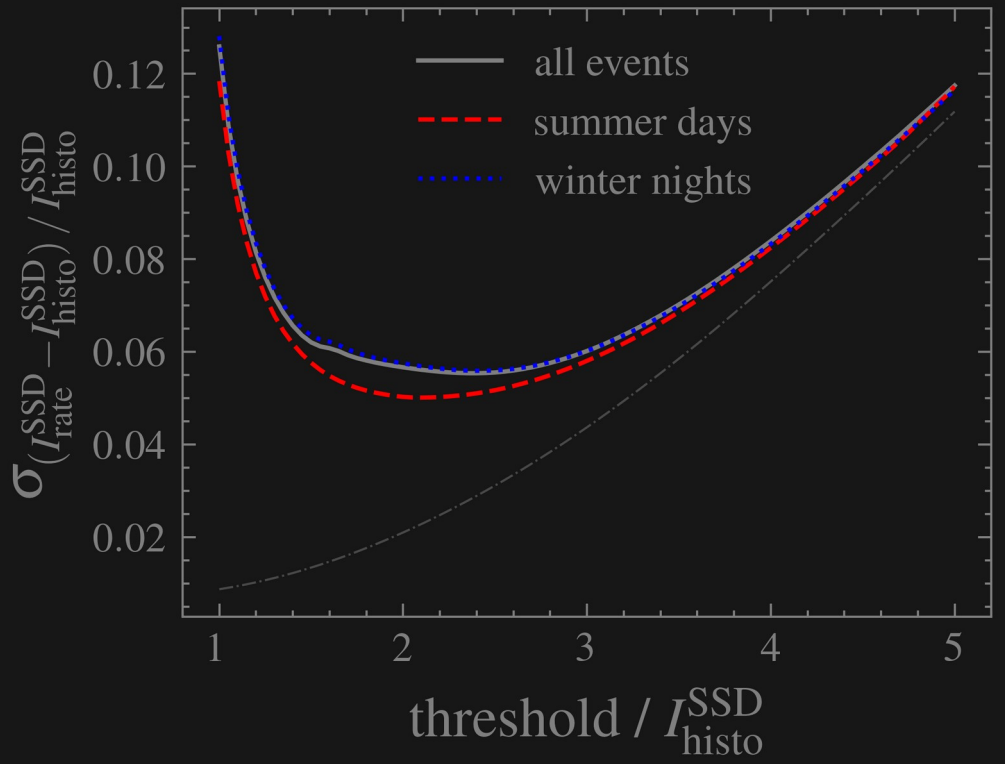
MIP ← Rate



- Similar behaviour across large projected temperature ranges

Performance of simple rate-based algorithm





- Small bias (<3%) for all considered thresholds
- Error of ~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 → but lower rate! Higher error!

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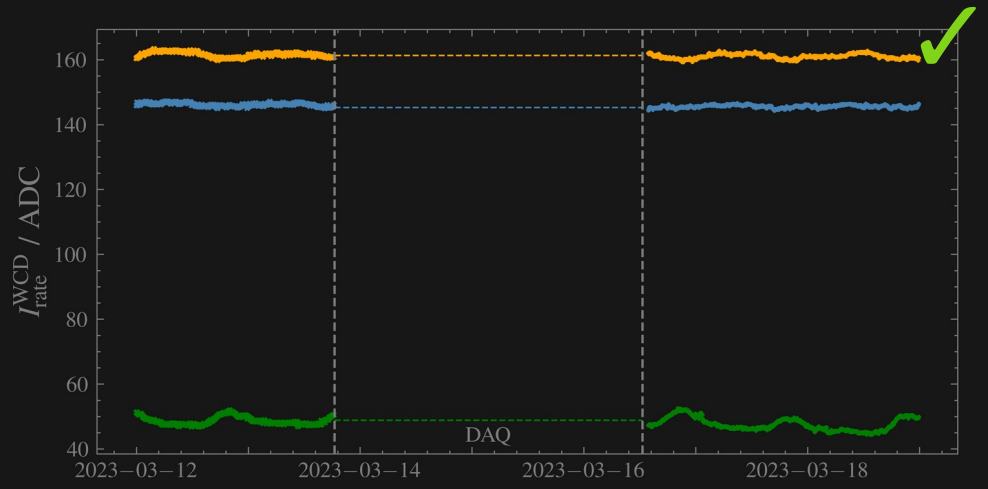
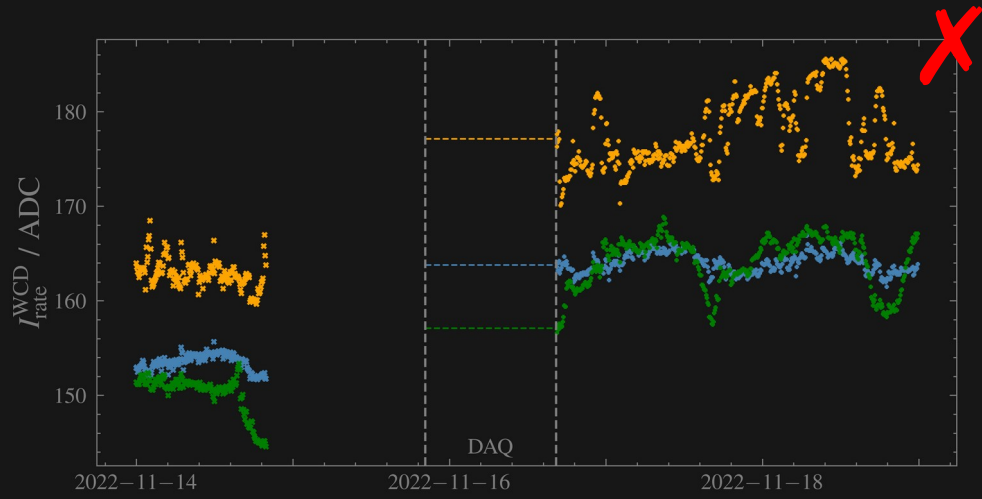
estimate from UUB randoms

Caveat: T1 preselection

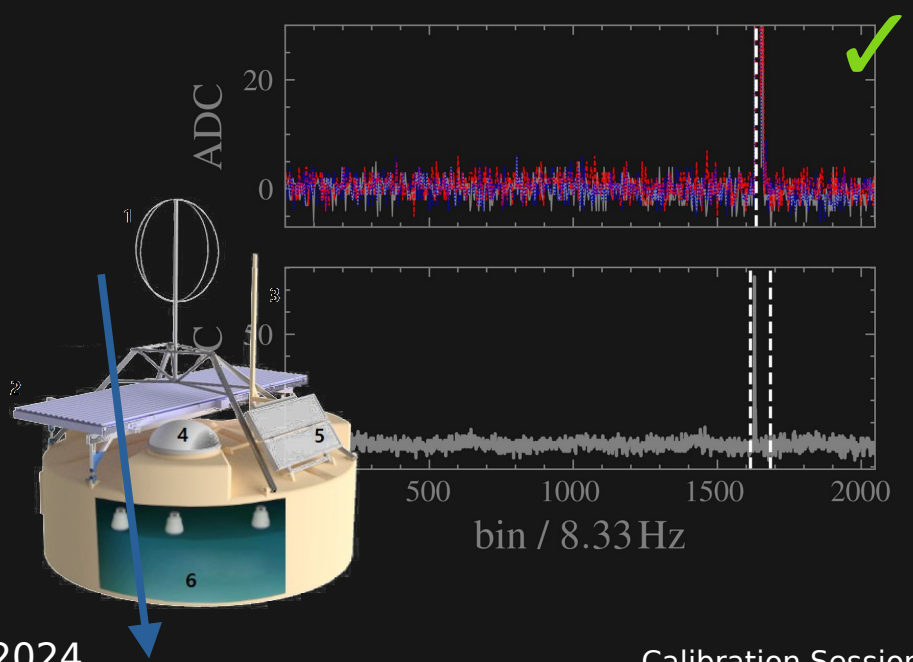
- Build SSD pulse height histogram for stations that have:
  - Online calibration functioning for all 3 PMTs 10/12 stations
  - Fluctuations of $I_{\text{rate}}^{\text{WCD}}$ before/after DAQ <5% 8/12 stations
  - Jump in $I_{\text{rate}}^{\text{WCD}}$ before after DAQ <10% 4/12 stations

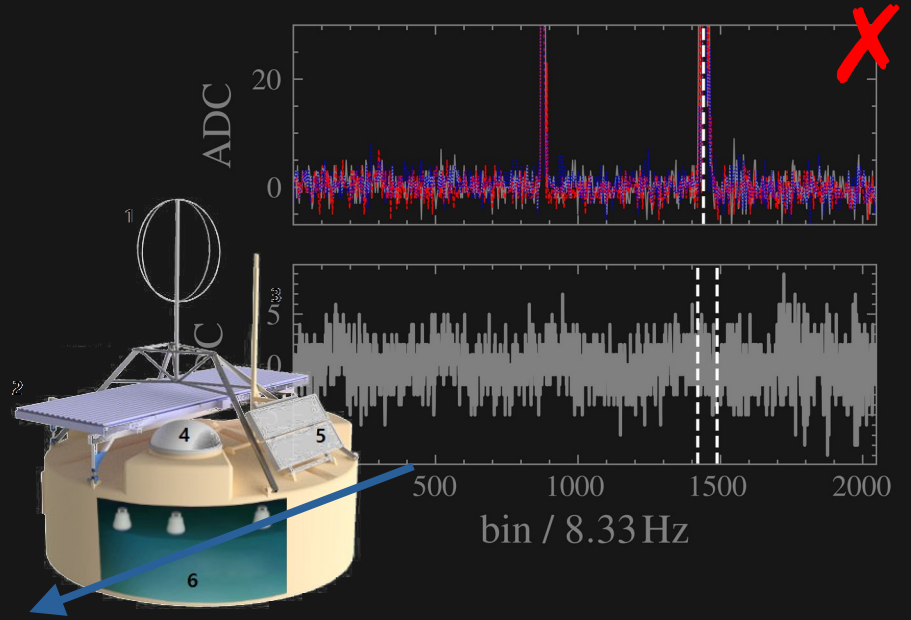




Caveat: T1 preselection

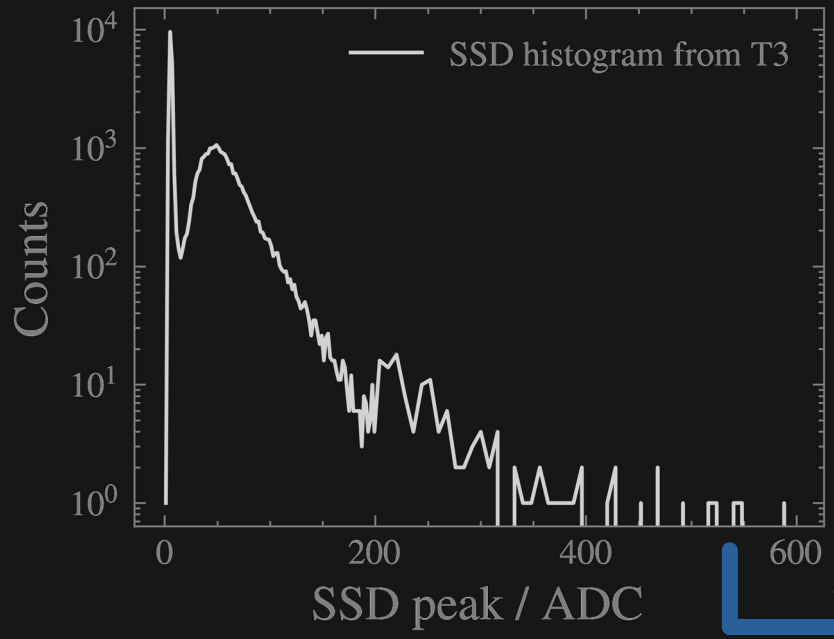
- Build SSD pulse height histogram from events that have:
  - T1 trigger in WCD trace ~100 Hz
  - Coincident SSD signal with T1 latch bin ~1-2% ?

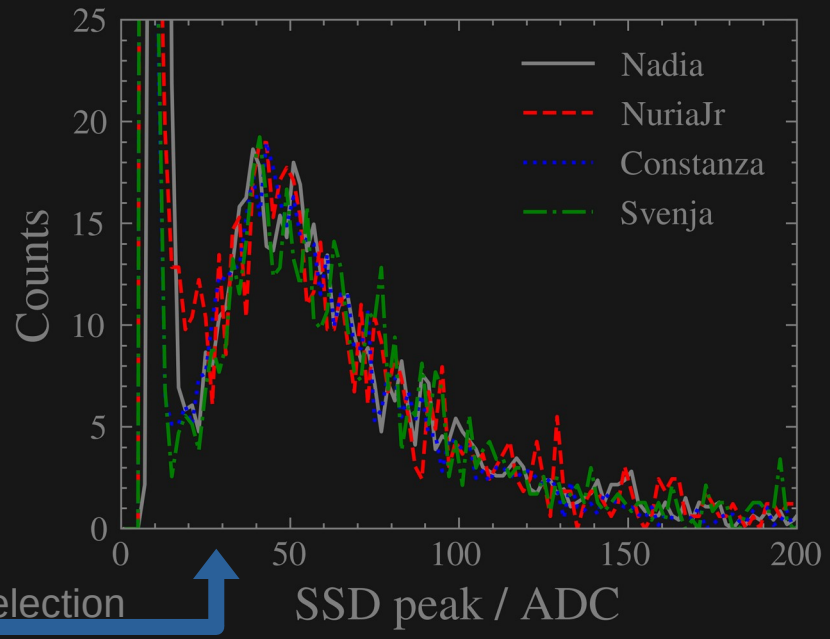




T1 preselection: statistical error

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

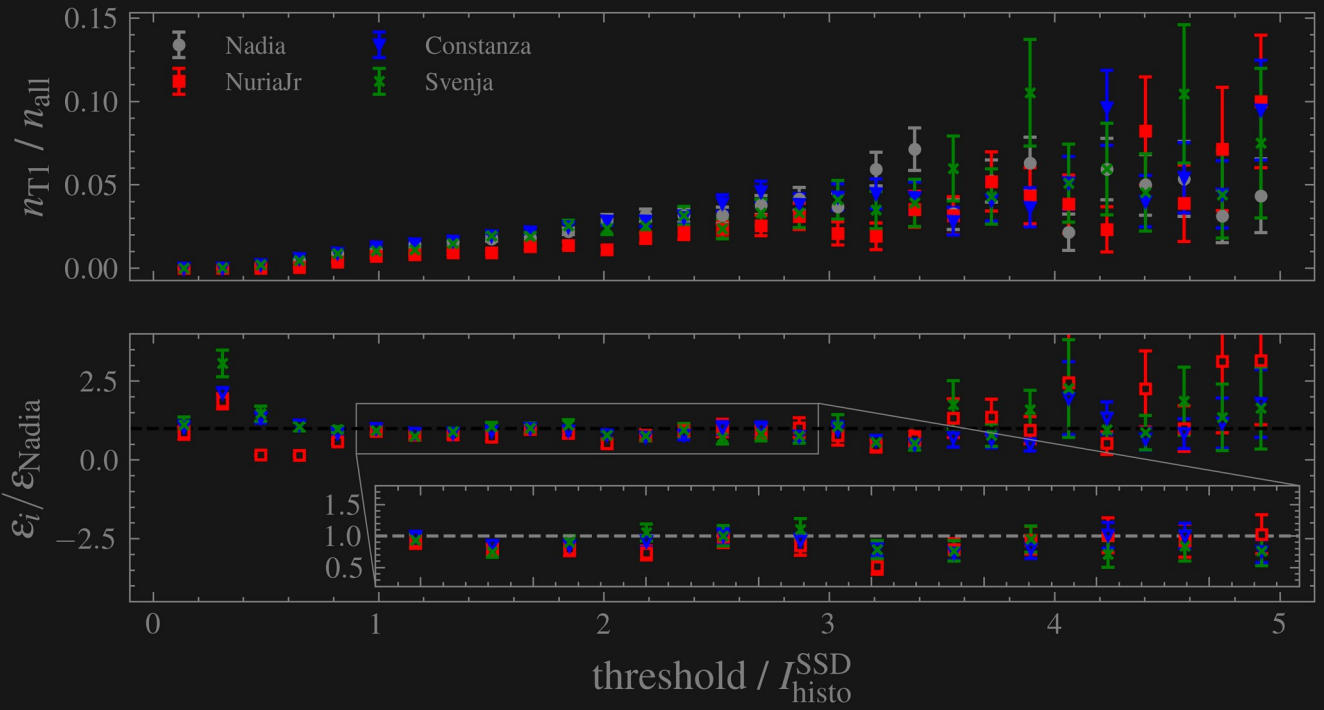




T1 preselection

T1 preselection: systematic error

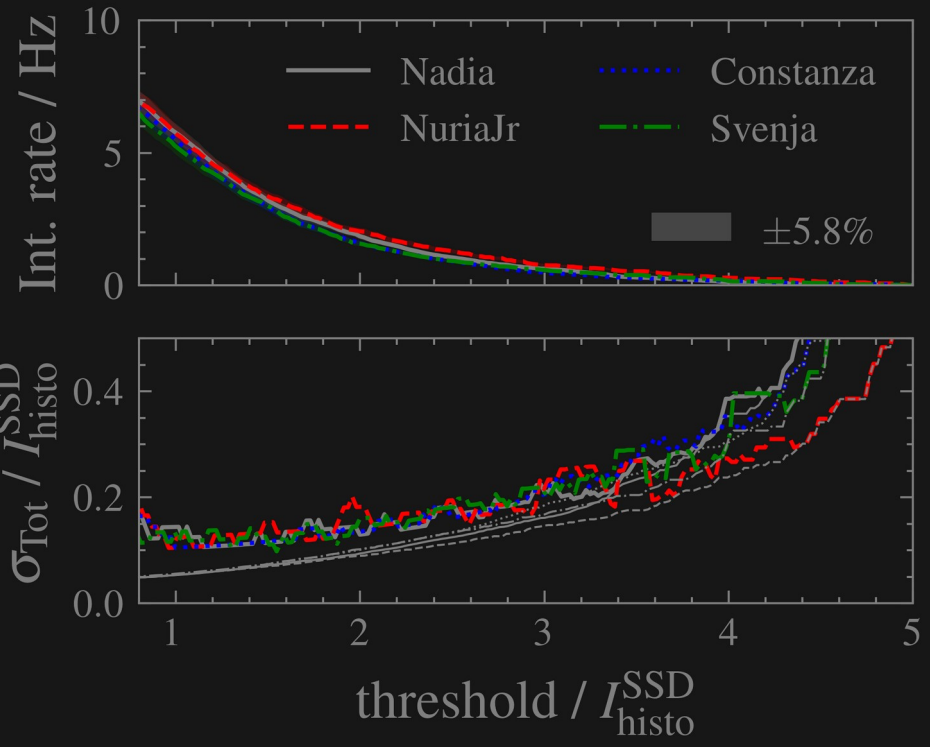
- Compare station-to-station fluctuations in T1 probability
- Analyze spread in region that showed minimal error



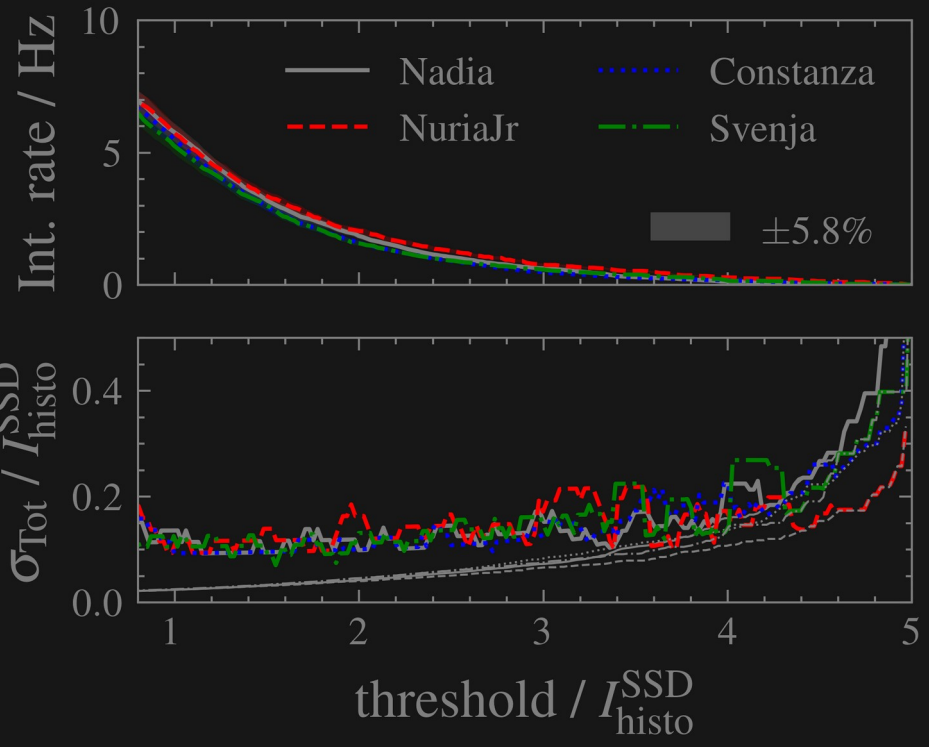
- ~10% fluctuation in RoI
- In line with expectations from T3 histograms
- Larger contribution to error on I^{SSD}_{rate} due to shallower rate profile!

T1 preselection: expected total error

- DAQ time 61s



- DAQ time 300s



Summary and outlook

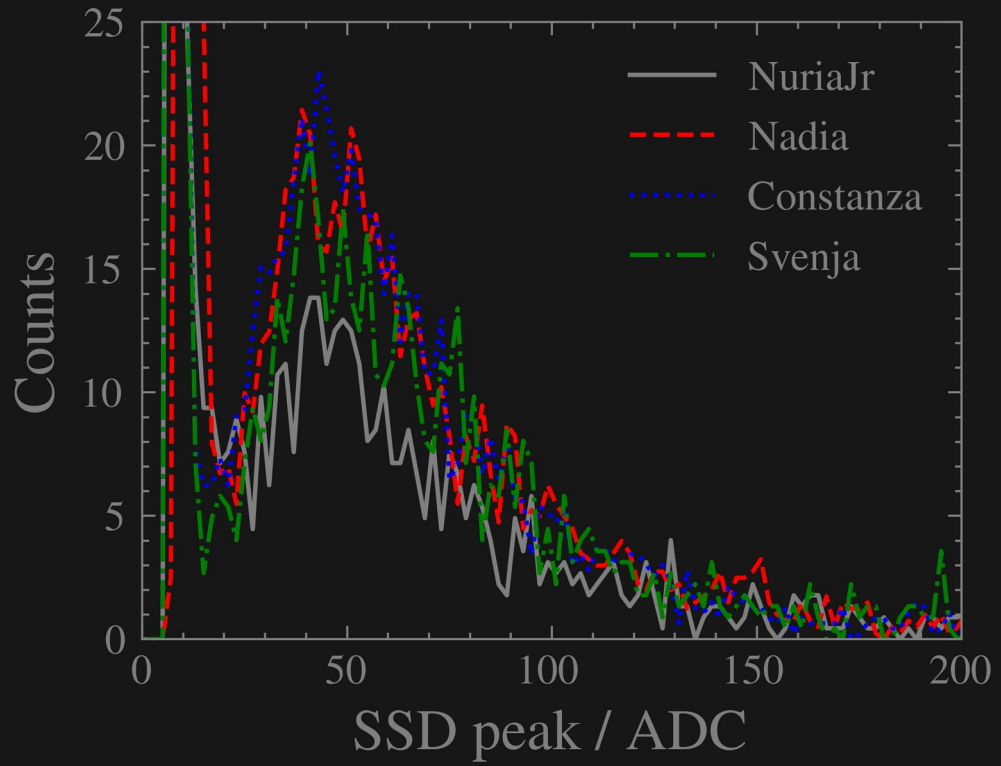
- Rate based algorithm for SSD online calibration shows small bias and acceptable precision for muonBuffer events
- T1-preselection simplifies implementation in station software
- Stricter selection criteria increase total error: ~10%
- Remains to be seen if presented method is precise enough
  - For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

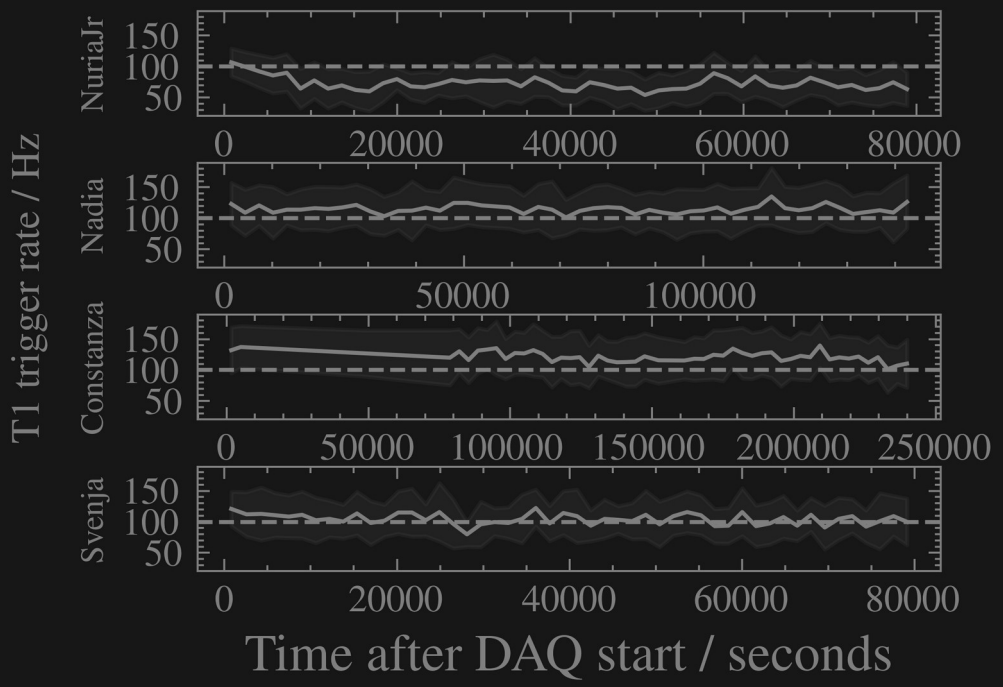
BACKUP

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

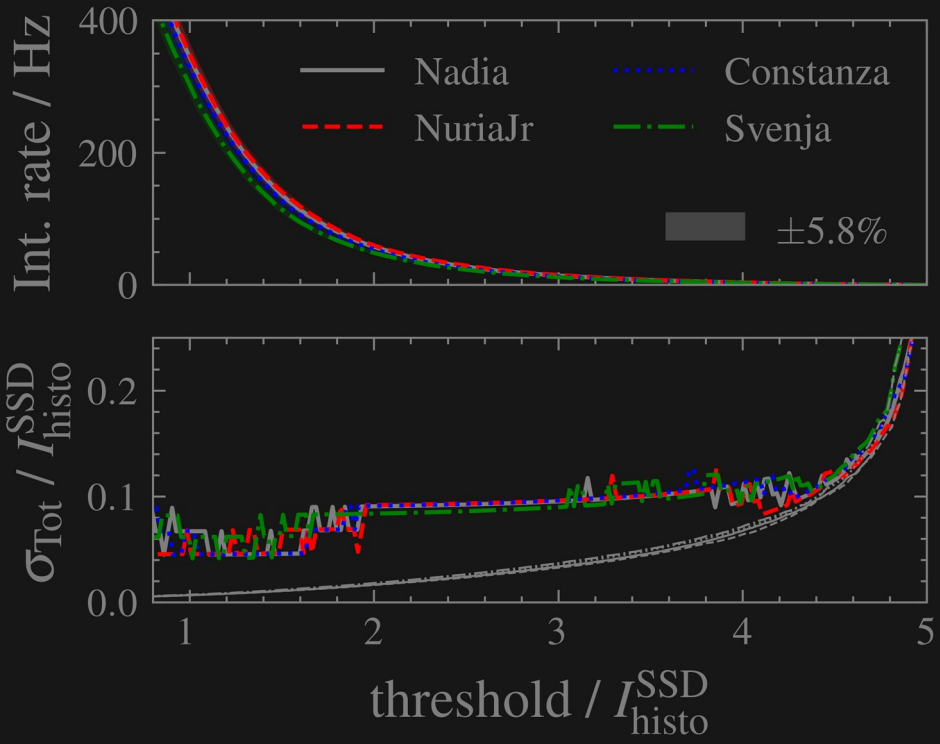




- Normalize counts by factor mean_rate / 100 Hz

No T1 preselection: expected total error

- DAQ time 61s



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