Karlsruhe Institute of Technology

PIERRE AUGER OBSERVATORY

Proposal for an algorithm for the online determination of the MIP peak in the UUB DAQ

SD/UMD Calibration Call 30.10.23

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Calibration method idea

- Estimate $I^{\text{est.}}_{\text{MIP}}$ (SSD) similar to how $I^{\text{est.}}_{\text{VEM}}$ (WCD) is already estimated
- WCD calibration trigger requires
  - Coincidence of 3 PMTs above $\mathbf{1.75\ I^{est.}_{VEM}}$
  - Given PMT above $\mathbf{2.5\ I^{est.}_{VEM}}$
- Online algorithm sets thresholds such that **70 Hz** rate is achieved in all PMTs
- **Params** determined from reference tank
  - Yields 100 Hz (20 Hz) rate for T1 (T2) trigger

WCD Online Calibration Algorithm

(1) Start with a value of $I^{\text{est.}}_{\text{VEM}} = 50\,\text{ch}$.
(2) Measure, for each PMT, the rate of events satisfying the calibration trigger by counting these events for a time t_{cal}, initially set to 5 s.
(3) If, for a given PMT, the rate is above $70 + \sigma$ Hz, increase $I^{\text{est.}}_{\text{VEM}}$ by δ. Likewise, if the rate is below $70 - \sigma$ Hz, decrease $I^{\text{est.}}_{\text{VEM}}$ by δ, with $\sigma = 2$ Hz and $\delta = 1$ ch initially.
(4) If the rate of any single PMT is more than $10\,\sigma$ away from 70 Hz, adjust $I^{\text{est.}}_{\text{VEM}}$ by 5 ch in the appropriate direction, set t_{cal} to 10 s, $\delta = 1$ ch, and repeat from step (2).
(5) Otherwise, if $t_{\text{cal}} < 60$ s, increase t_{cal} by 5 s. If $\delta > 0.1$ ch, decrease δ by 0.1 ch, and repeat from step (2).

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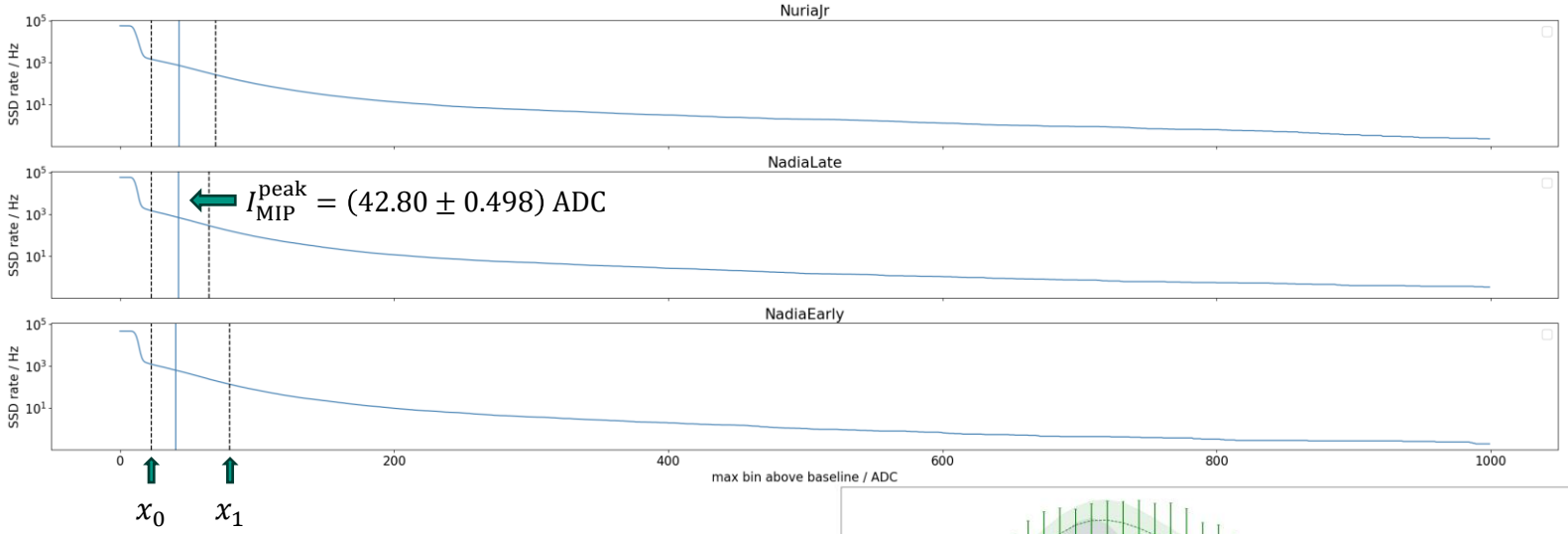
First check for stability

- Use UUBRandoms to compare rate based $I_{\mathrm{MIP}}^{\mathrm{est.}}$ estimate to histogram based $I_{\mathrm{MIP}}^{\mathrm{peak}}$
  - Two datasets with timing information: Nov. 2022 (6 stations), Mar. 2023 (6 stations)
  - Reject stations with large fluctuations in $I_{\mathrm{VEM}}^{\mathrm{est.}}$: 2 surviving stations ⟹ ~ 10 mil. traces
- Build histogram of maximum values for full bandwidth SSD traces
  - Assert exponential background in tail-end of the spectrum
  - Fit Landau distribution to residuals of histogram – exponential background
  - Set $I_{\mathrm{MIP}}^{\mathrm{est.}}$ as the (numerical) mean of Landau distribution

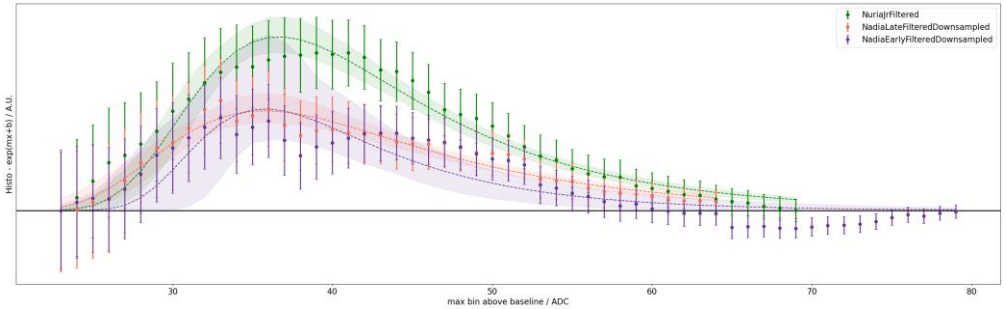
First check for stability



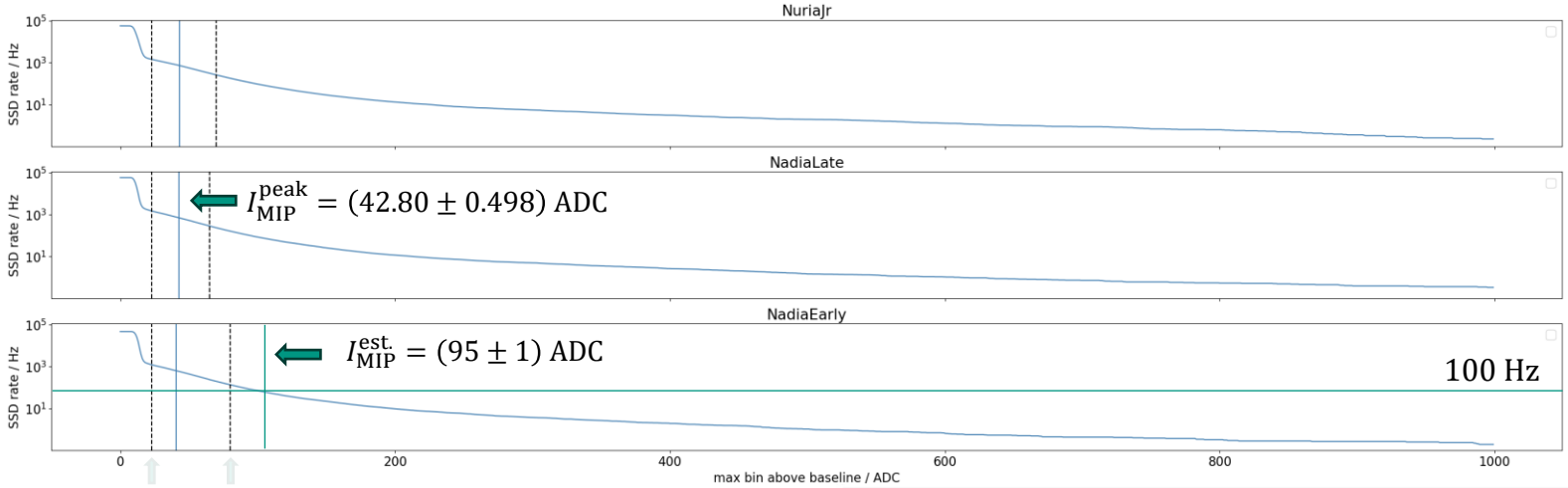
$$\mathrm{res}(x) = \mathrm{histo}(x) - A\exp\left(-m(x - x_0)\right),$$

and $m = -\log\left(\frac{histo(x_1)}{histo(x_0)}\right)/(x_1 - x_0)$

with $\mathrm{A} = \mathrm{histo}(x_0)$,



First check for stability



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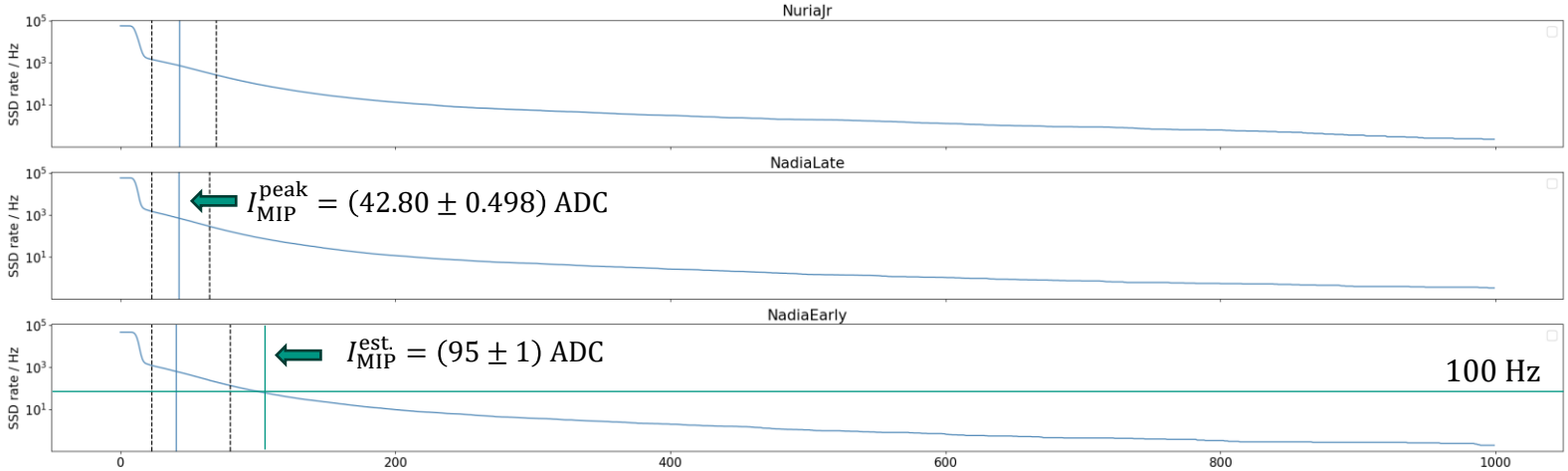
First check for stability



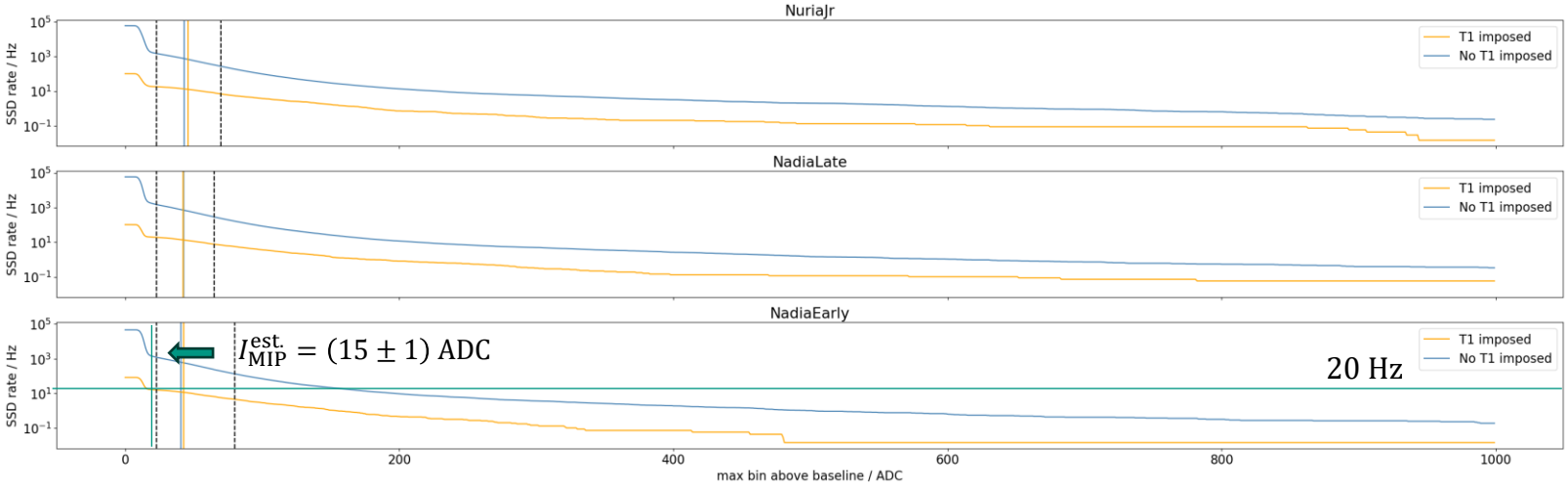
	$I_{\mathrm{MIP}}^{\mathrm{peak}}$ / ADC	$I_{\mathrm{MIP}}^{\mathrm{est.}}$ / ADC	$I_{\mathrm{MIP}}^{\mathrm{est.}} / I_{\mathrm{MIP}}^{\mathrm{peak}}$
NuriaJr	42.95 ± 0.36	99 ± 1	2.31 ± 0.019
NadiaLate	42.80 ± 0.498	95 ± 1	2.22 ± 0.035
NadiaEarly	40.79 ± 1.11	88 ± 1	2.16 ± 0.064

All stations within ≈ 5% of one another. Good first sign

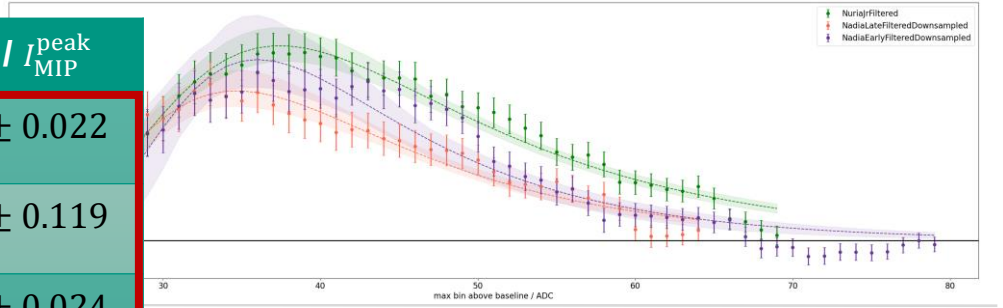
First check for stability

- Calibration procedure (software level) reliant on T1 formation (FPGA level)
  - T1 trigger = all WCD PMTs above $1.75\ I_{\mathrm{VEM}}^{\mathrm{est.}}$ in same bin
  - Historical reasons
- Much easier to implement SSD online calibration algorithm with this in mind
  - Rerun analysis with T1 preselected SSD traces
  - Results agree, but rates are lower ⟹ worse statistics!

First check for stability



	$I^{\text{peak}}_{\text{MIP}}$ / ADC	$I^{\text{est.}}_{\text{MIP}}$ / ADC	$I^{\text{est.}}_{\text{MIP}}$ / $I^{\text{peak}}_{\text{MIP}}$
NuriaJr	46.92 ± 0.347	17 ± 1	0.37 ± 0.022
NadiaLate	42.22 ± 0.447	19 ± 5	0.47 ± 0.119
NadiaEarly	42.78 ± 0.593	15 ± 1	0.35 ± 0.024

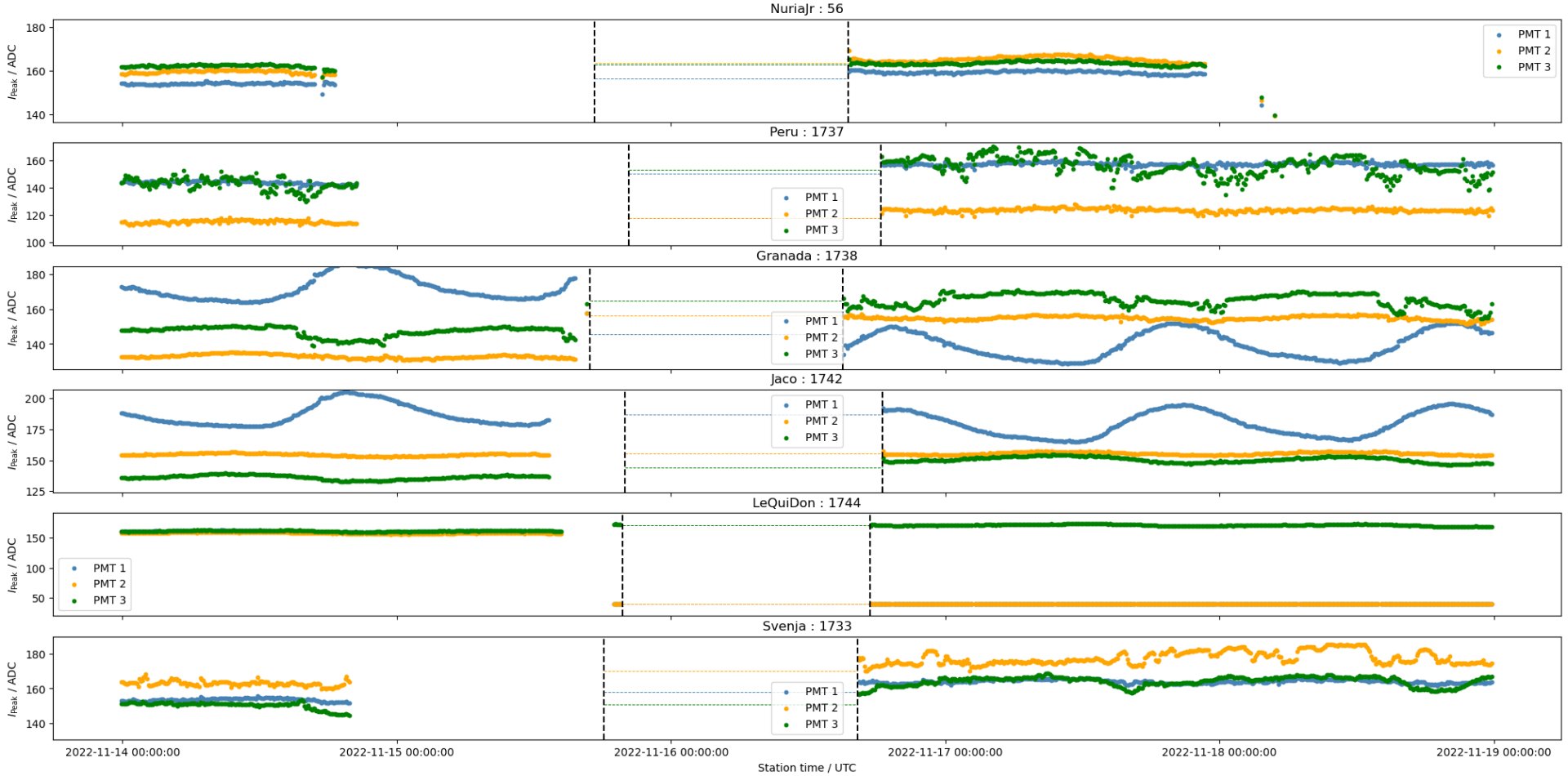


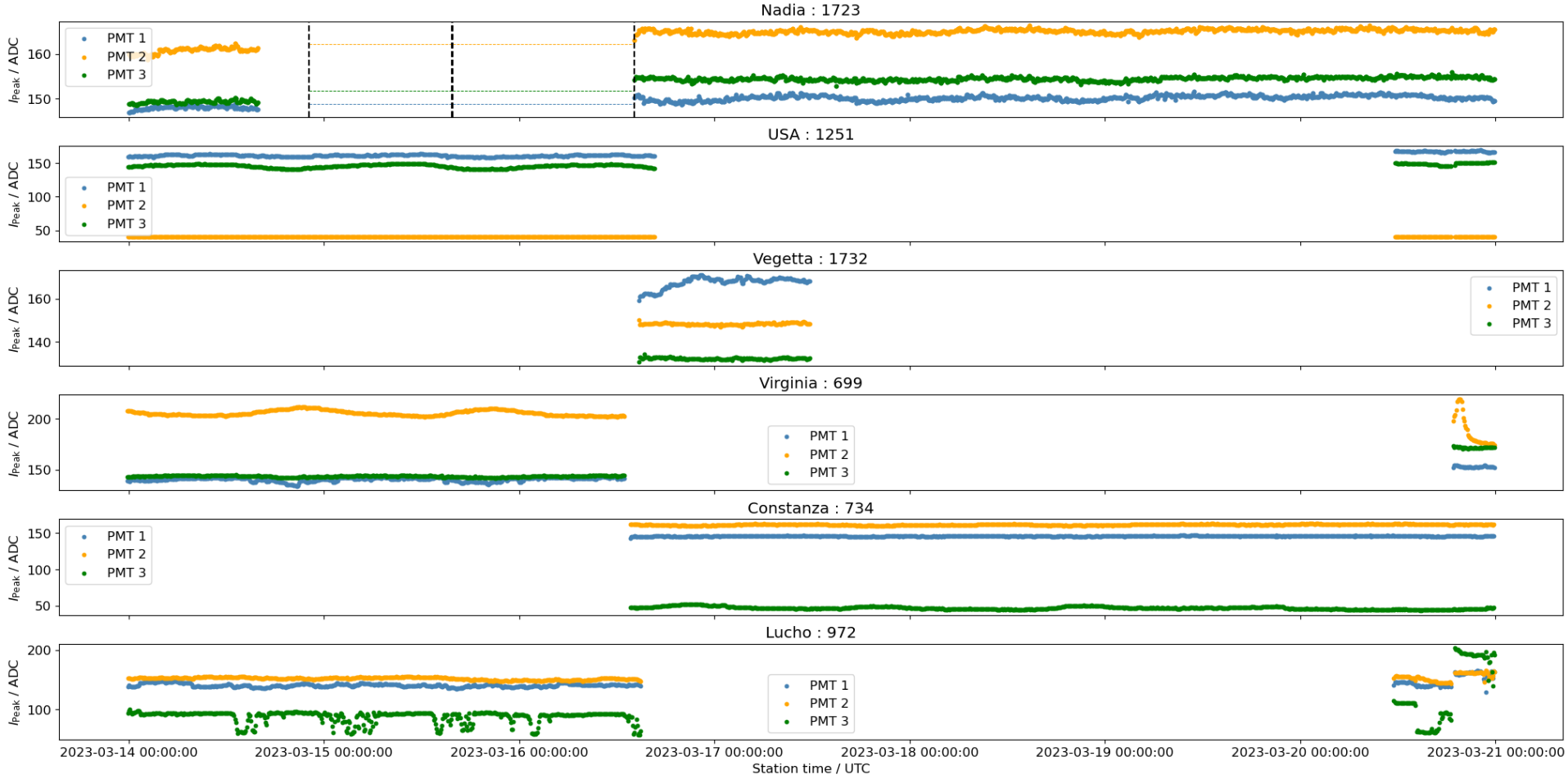
Summary & Next steps

- Rate based online estimate of $I_{\mathrm{MIP}}^{\mathrm{est.}}$ seems possible at first glance
- T1 preselection might complicate things, more data needed to say for sure

- Check T3 data and compare UUBRandom histogram peak to offline reported $I_{\mathrm{MIP}}^{\mathrm{peak}}$
- Quantify bias, std and error on $I_{\mathrm{MIP}}^{\mathrm{est.}}$ for various target rates, ideally with special dataset
- Your ideas

Backup


NuriaJr : 56
Peru : 1737
Granada : 1738
Jaco : 1742
LeQuiDon : 1744
Svenja : 1733
I_{Peak} / ADC
PMT 1
PMT 2
PMT 3
2022-11-14 00:00:00
2022-11-15 00:00:00
2022-11-16 00:00:00
2022-11-17 00:00:00
2022-11-18 00:00:00
2022-11-19 00:00:00
Station time / UTC


Nadia : 1723
USA : 1251
Vegetta : 1732
Virginia : 699
Constanza : 734
Lucho : 972
PMT 1
PMT 2
PMT 3
I_{Peak} / ADC
2023-03-14 00:00:00
2023-03-15 00:00:00
2023-03-16 00:00:00
2023-03-17 00:00:00
2023-03-18 00:00:00
2023-03-19 00:00:00
2023-03-20 00:00:00
2023-03-21 00:00:00
Station time / UTC