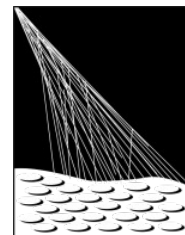


Towards a rate-based online calibration of the SSD MIP peak

Paul Filip, David Schmidt



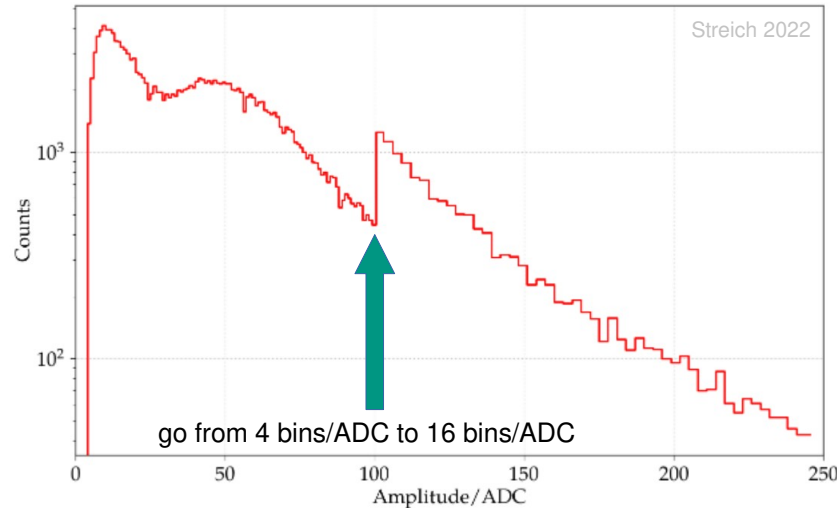
PIERRE
AUGER
OBSERVATORY



Idea & terminology

WCD offline calibration algorithm

- Fit muon hump in muon histogram



WCD online calibration algorithm

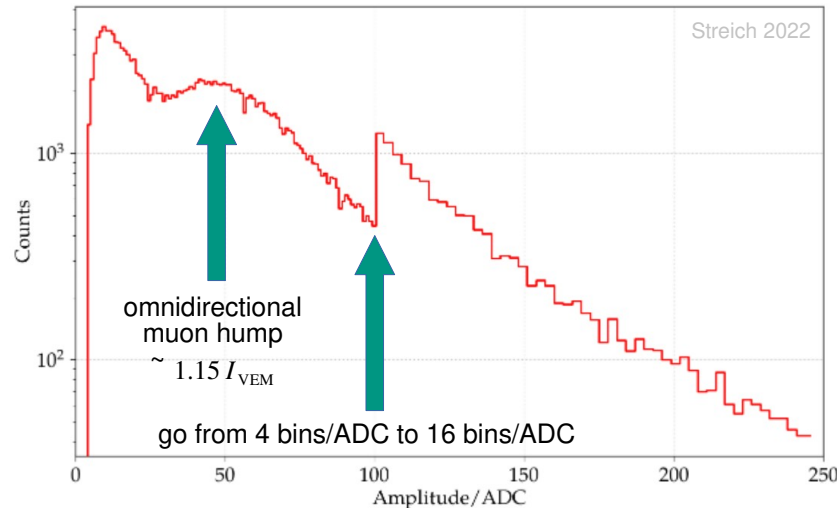
- (1) Start with a value of $I_{\text{VEM}}^{\text{est.}} = 50$ ch.
- (2) Measure, for each PMT, the rate of events satisfying the calibration trigger by counting these events for a time t_{cal} , initially set to 5 s.
- (3) If, for a given PMT, the rate is above $70 + \sigma$ Hz, increase $I_{\text{VEM}}^{\text{est.}}$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

doi.org/10.1016/j.nima.2006.07.066

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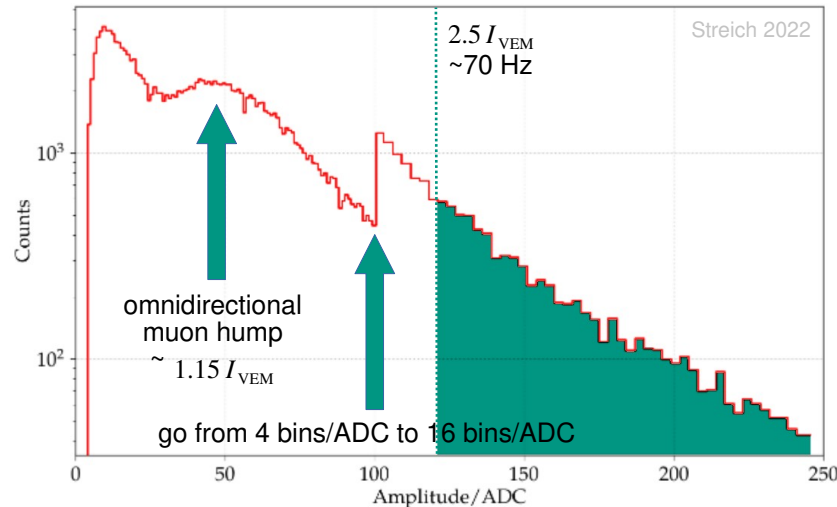
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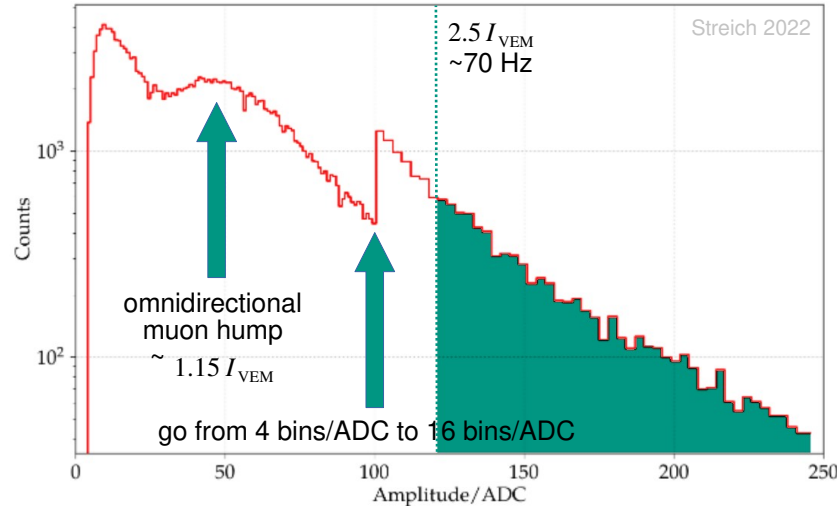
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LACK THIS ALGO-RITHM FOR SSD!

Idea & terminology

- I_{VEM} – most probable pulse height in the WCD for a VCT muon
- Q_{VEM} – most probable (integral) charge in the WCD for a VCT muon

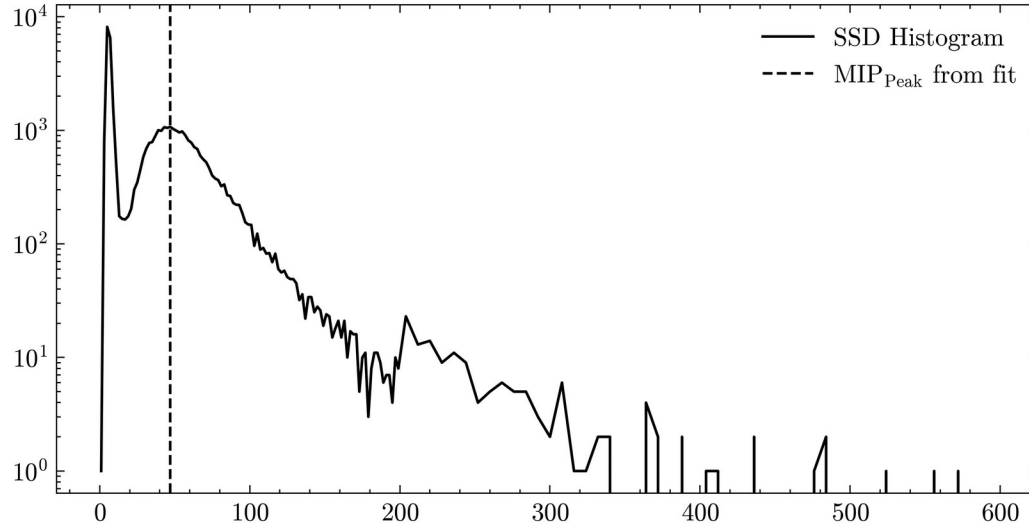
- $I_{\text{histo}}^{\text{WCD}}$ – peak location of the parabola fitted to WCD muon hump
- $I_{\text{rate}}^{\text{WCD}}$ – threshold of WCD calibration trigger for which have 70 Hz rate

new

- I_{VEM} – ... in the SSD ...
- Q_{VEM} – ... in the SSD ...
- $I_{\text{histo}}^{\text{SSD}}$ – peak location of the parabola fitted to SSD muon hump
- $I_{\text{rate}}^{\text{SSD}}$ – threshold of SSD calibration trigger for which have predetermined rate

Setting up rate/threshold relationship

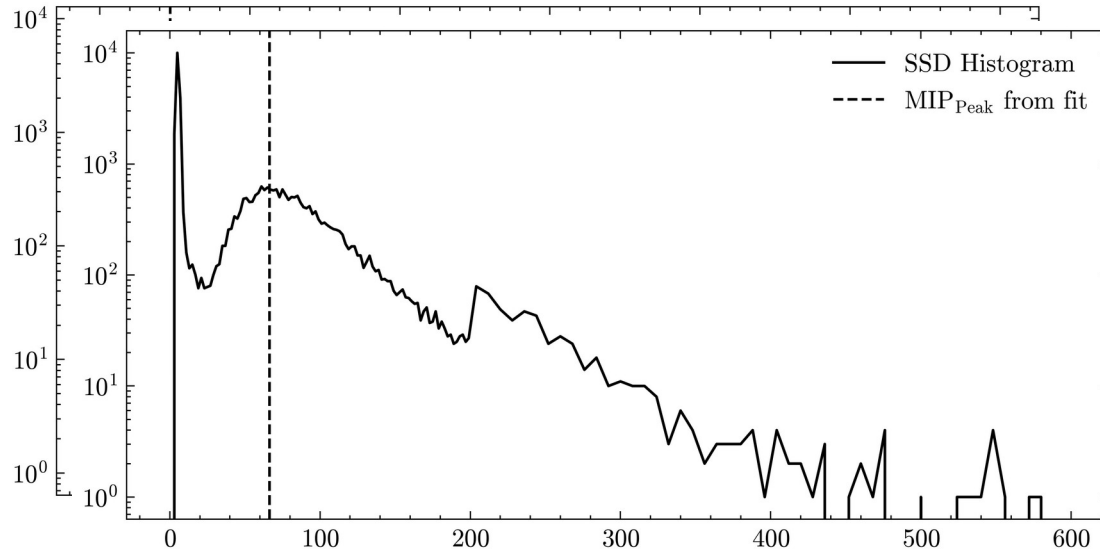
- 870,000 SSD histograms from SD-1500 T3s in Jun/Dec 2023
- Bootstrap muon events according to SSD histogram to estimate $I_{\text{histo}}^{\text{SSD}}$



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

Setting up rate/threshold relationship

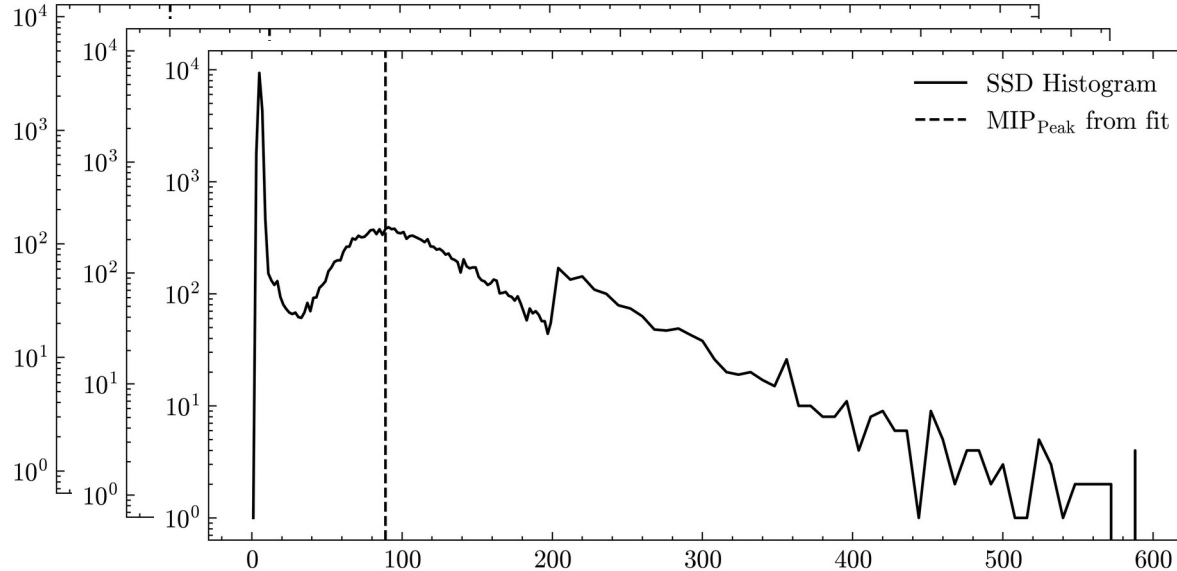
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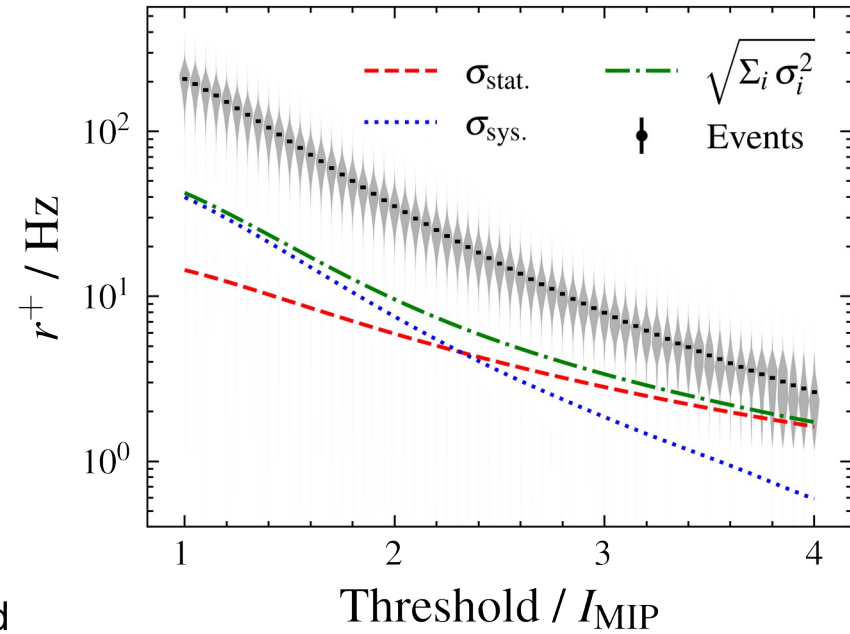
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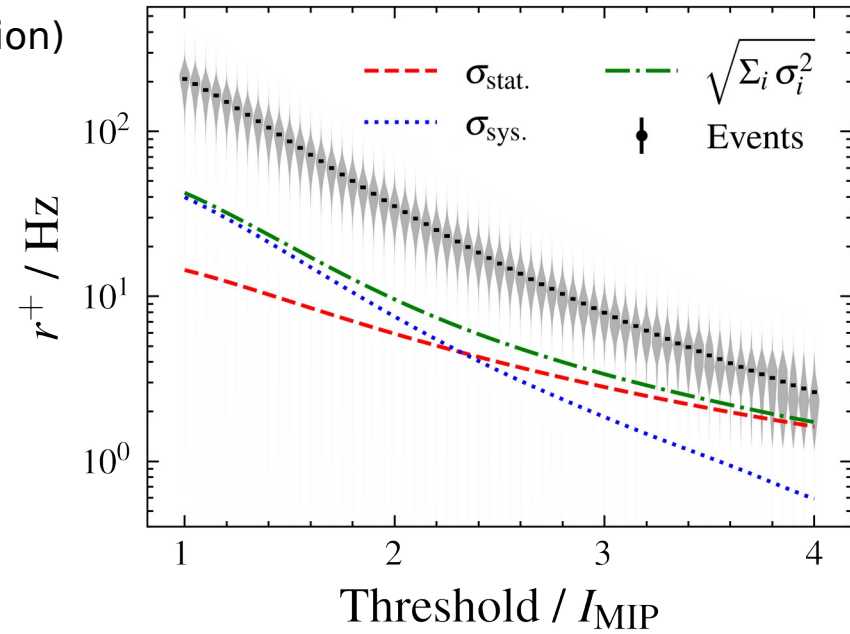
MIP \rightarrow Rate

- Fit MIP from histogram to obtain $I_{\text{histo}}^{\text{SSD}}$
- For threshold in $\{1.00, 1.05, \dots, 5.00\} I_{\text{Histo}}^{\text{SSD}}$:
 - Count all entries above given threshold
 - Per station: remove outlier events at 3σ
 - Per station: take mean of samples
 - Divide by histogram acquisition time (61s)
 - Average across stations
- systematic: station-to-station fluctuations $\sim 20\%$
- statistical: Poisson error on counts above threshold



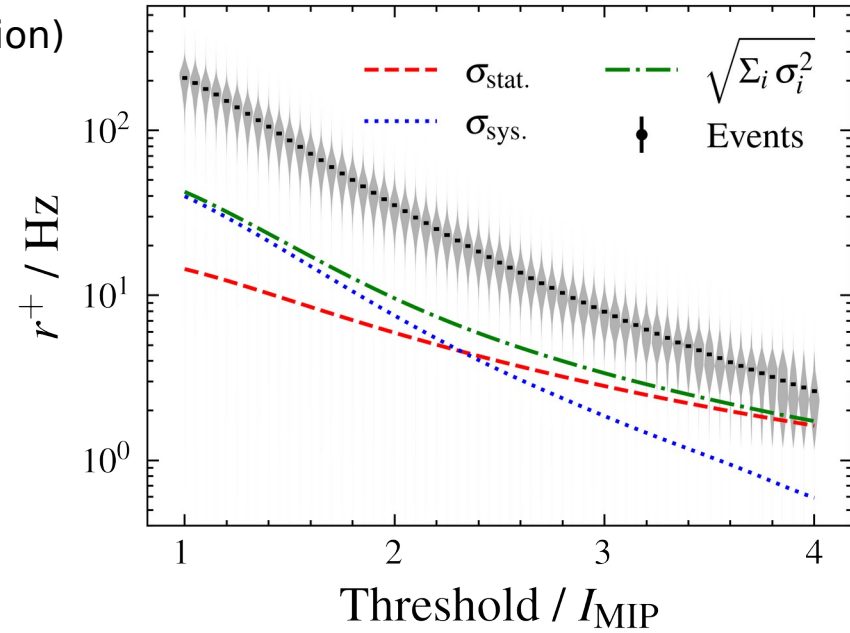
MIP ← Rate

- Adjust threshold t of SB calibration until rate f is met
- $I_{\text{rate}}^{\text{SSD}}$ given as kt (take k , f from rate/threshold relation)



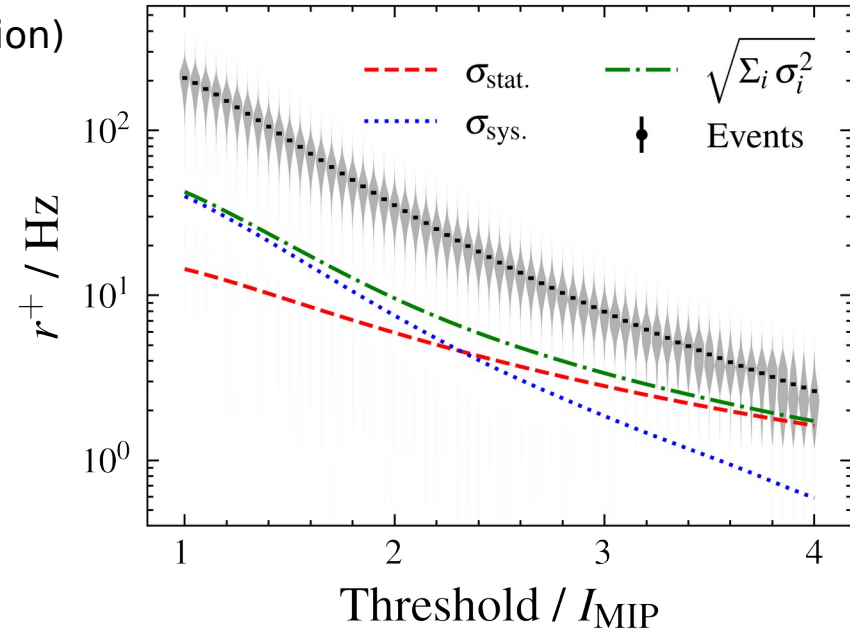
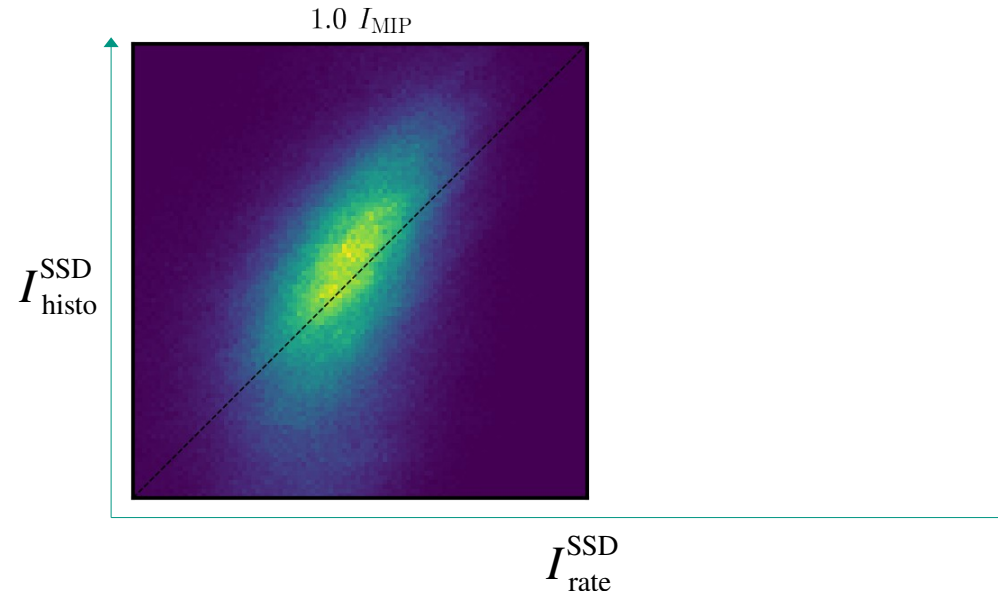
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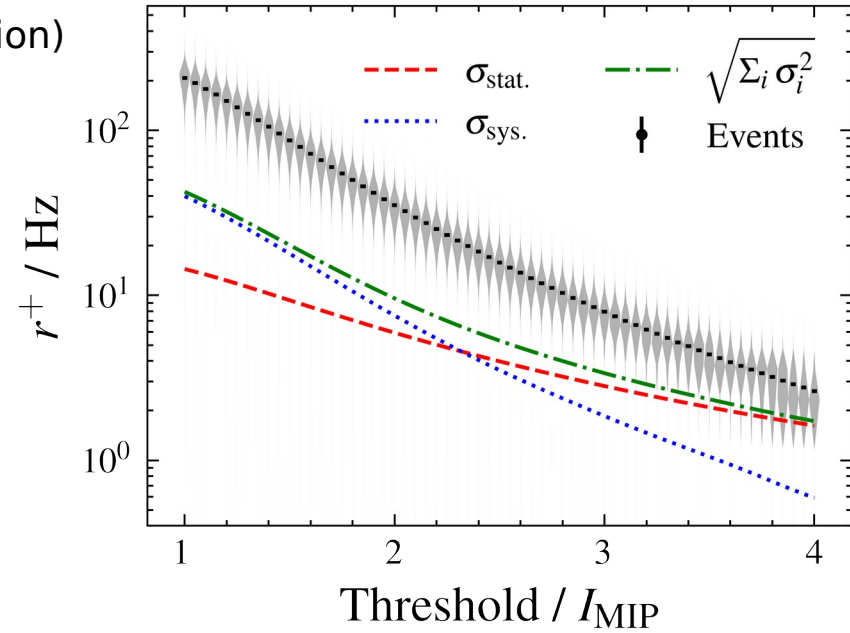
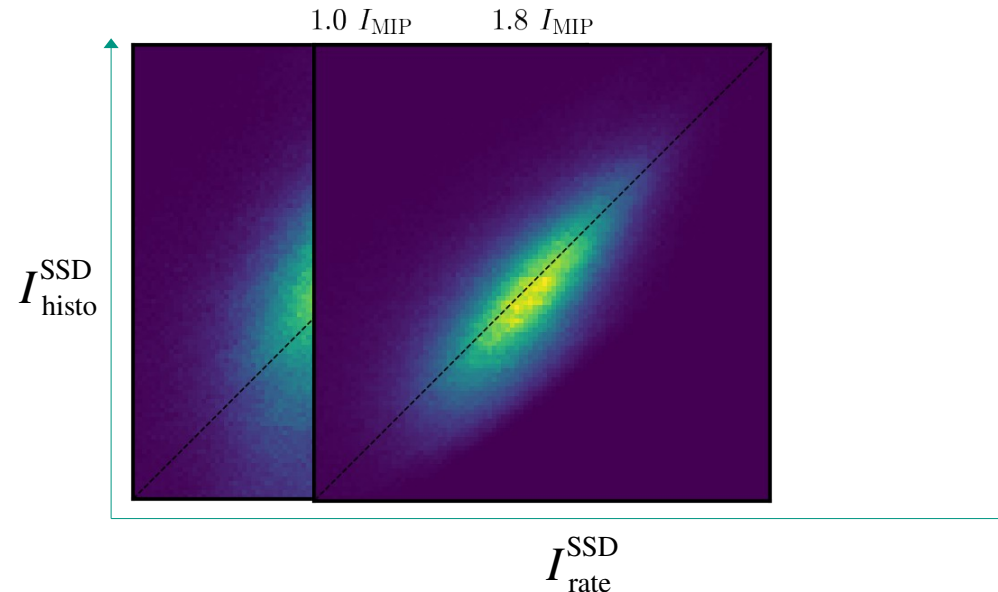
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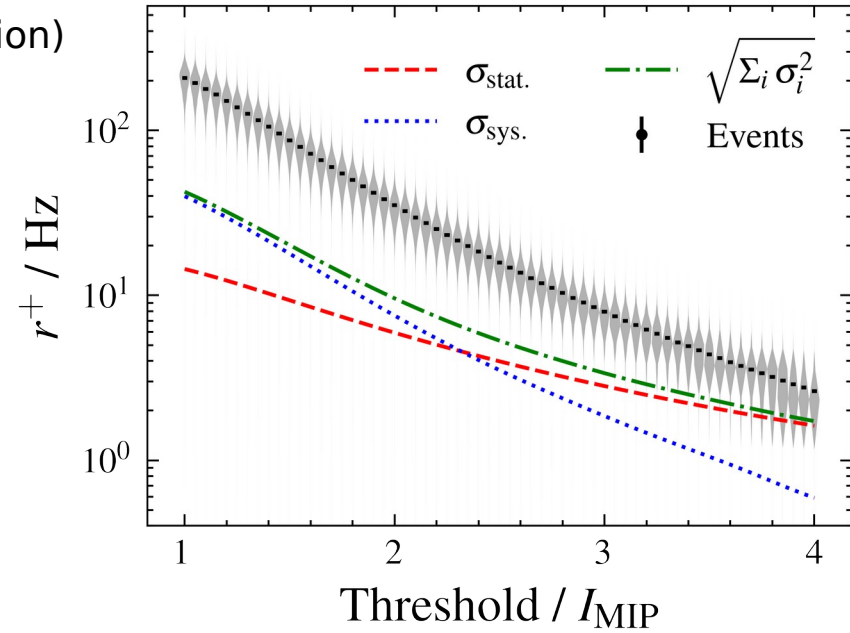
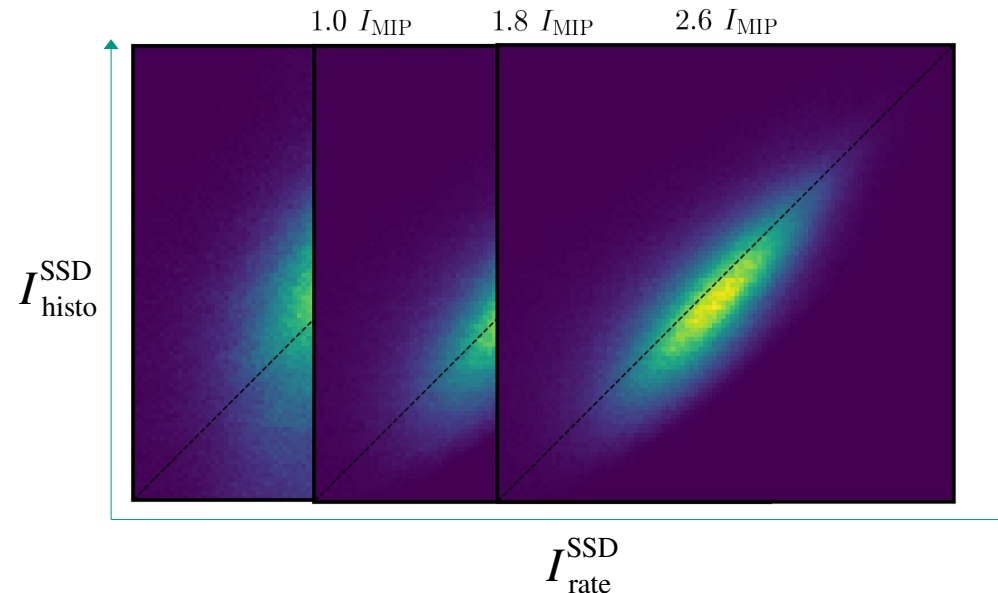
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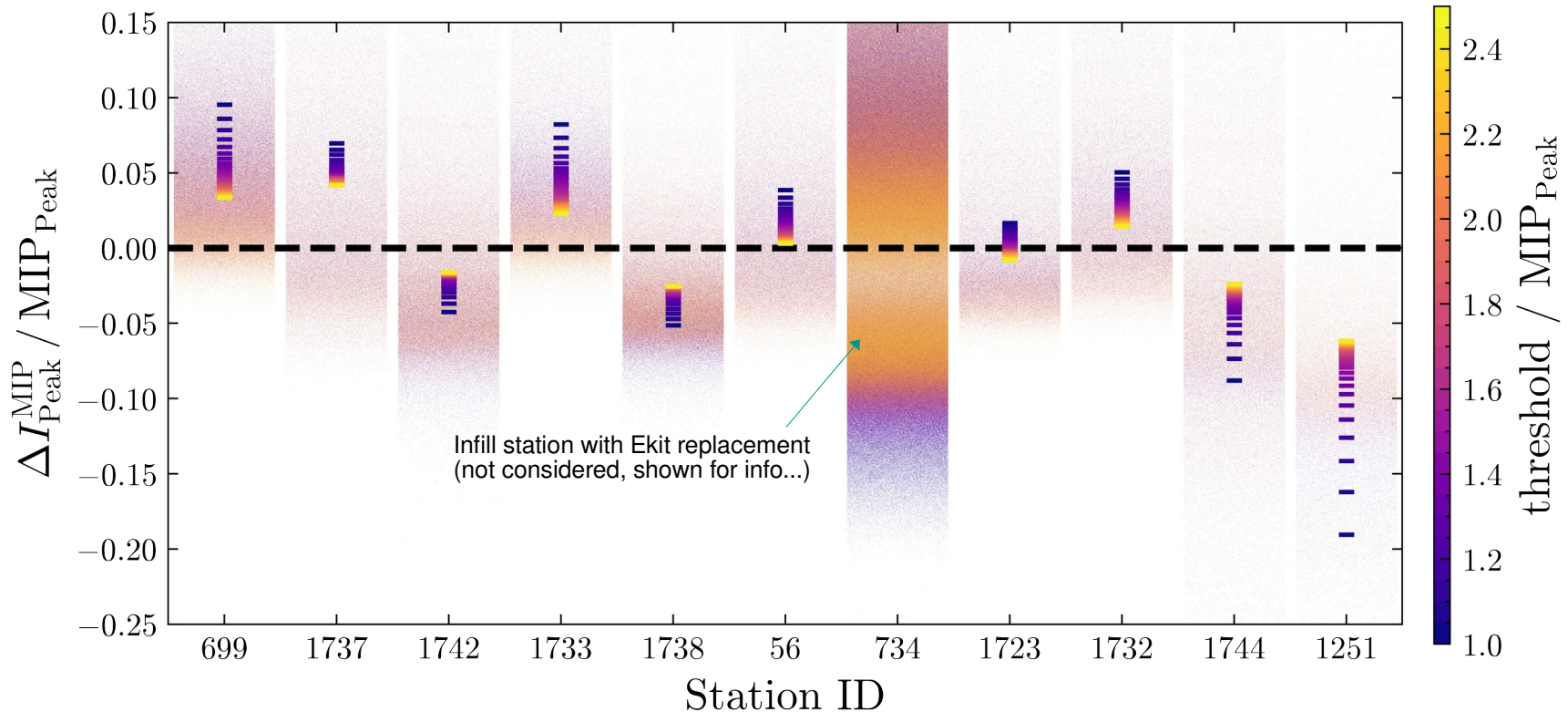


MIP ← Rate

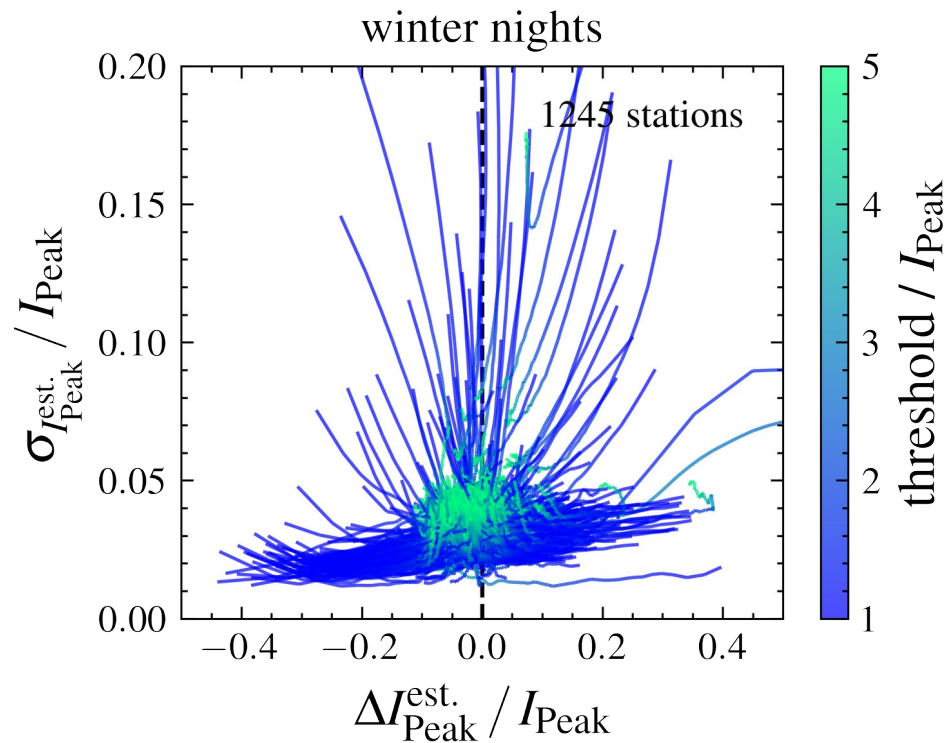
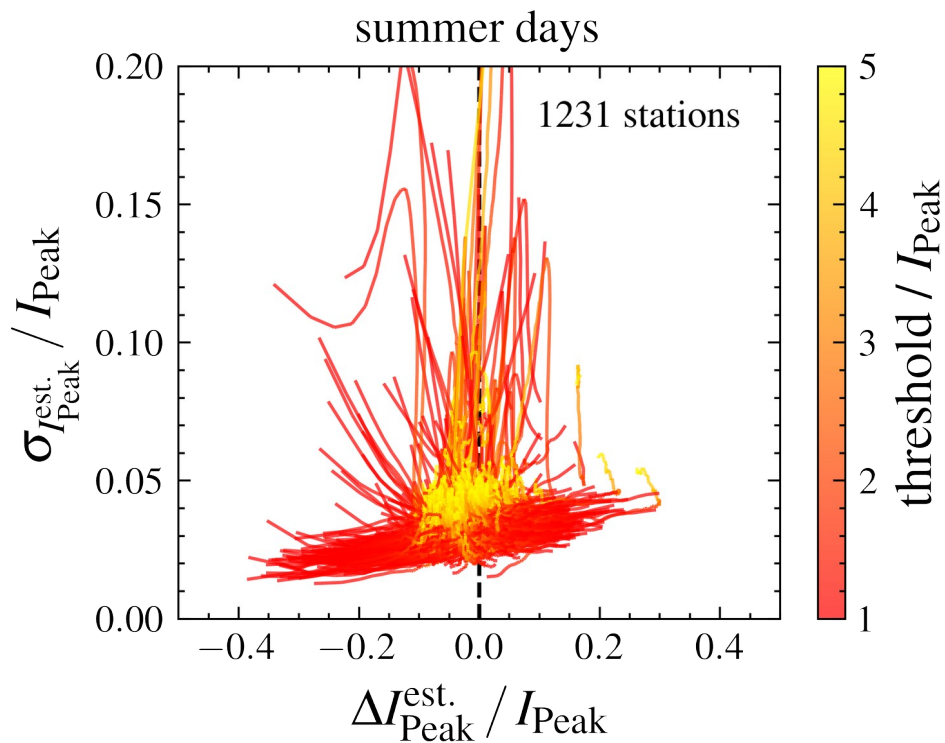
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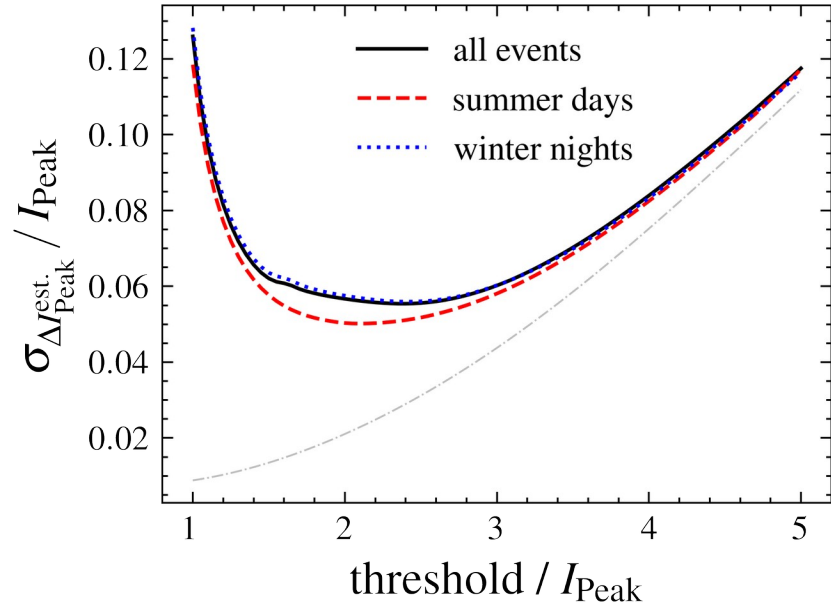
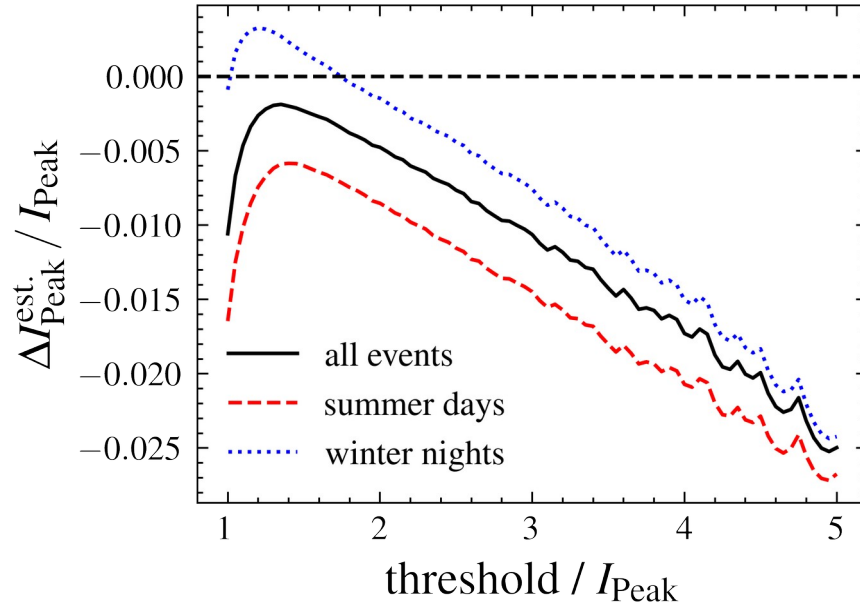
MIP ← Rate



MIP ← Rate



MIP Rate



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

Caveat: T1 preselection

- Rate/threshold relationship here derived for **MuonBuffer** events (>30 ADC above baseline)
- Online calibration performed on **ShowerBuffer** events ($>1.75 I_{\text{MIP}}$ above baseline)

Caveat: T1 preselection

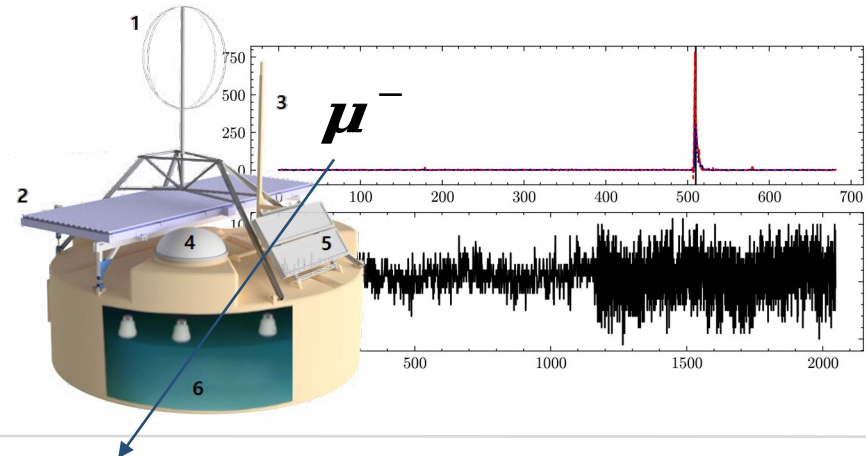
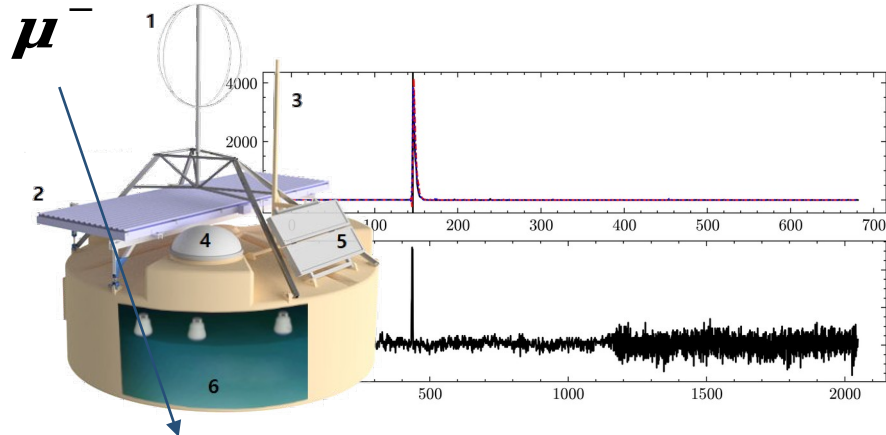
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- **But** less events! \rightarrow higher Poissonian error expected \rightarrow too high to be useful for us?

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estimate from UUB Randoms

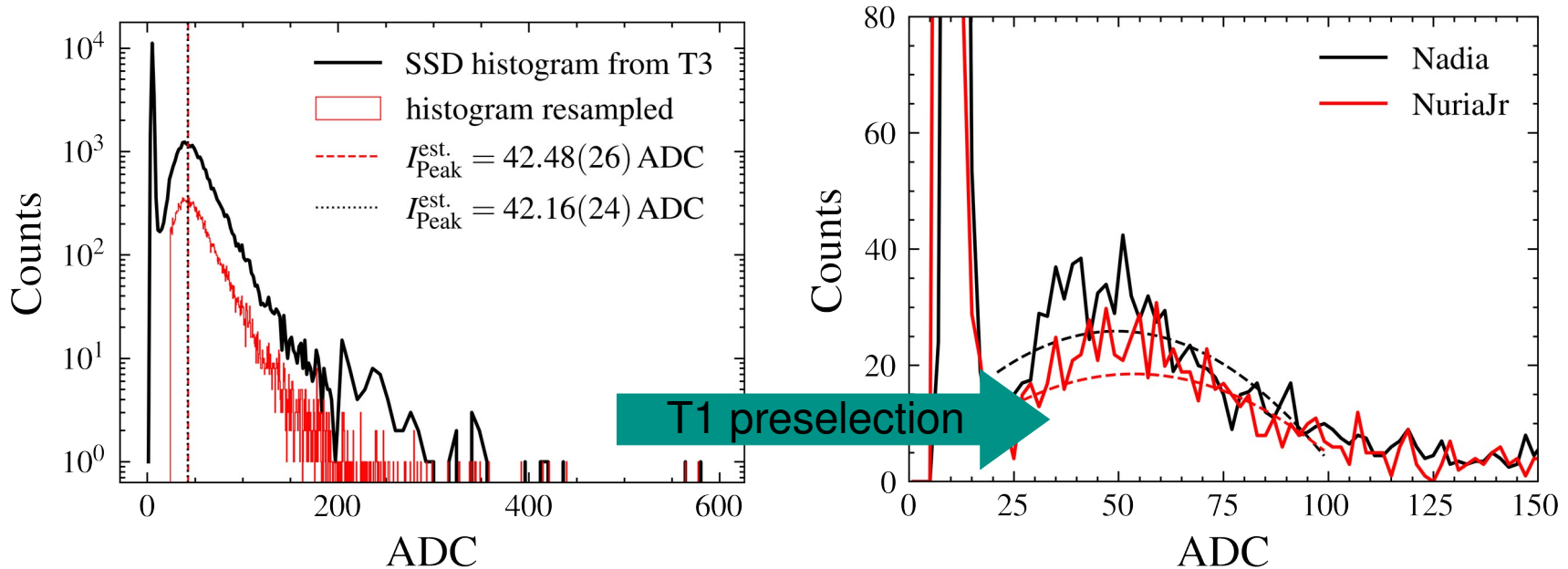
Caveat: T1 preselection

- Build SSD pulse height histogram from events that satisfy the following:
 - Corresponding WCD traces satisfies a WCD T1
 - Max. SSD pulse height occurs at most 19 (40) bins before (after) T1 latch bin

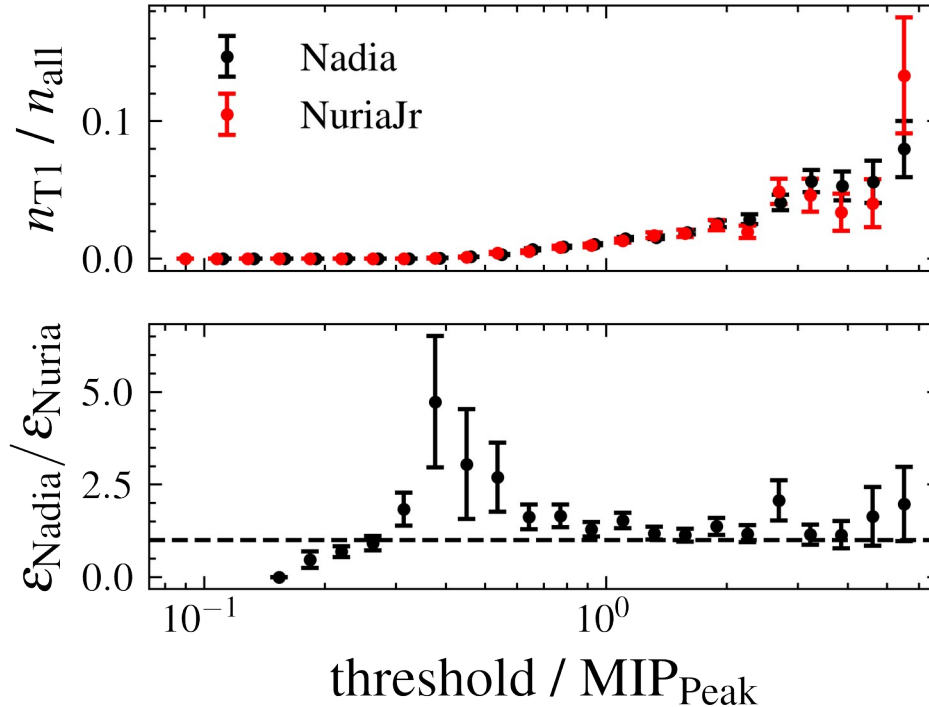


Caveat: T1 preselection

- Rate drops by factor ~ 100 , associated Poisson error becomes 5-12% (1.5-4% before)



Caveat: T1 preselection



- SSD events implicitly rely on T1 efficiency
- T1 efficiency might differ across stations...?
- First look: compatible for higher thresholds
- Difficult to make more precise statements with limited UUB randoms dataset
- need to extend analysis

Summary / Outlook

- Rate-based calibration in principle for I_{MIP} possible based on SB calibration trigger
- (As of now) unclear whether (useful) rate/threshold relations exists for T1 selected traces
- Revisit quality cuts for UUB Randoms and perform analysis for new stations
- Decide on implementation strategy for SSD online calibration