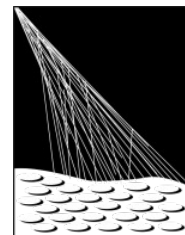


# Towards a rate-based online calibration of the SSD MIP peak

Paul Filip, David Schmidt



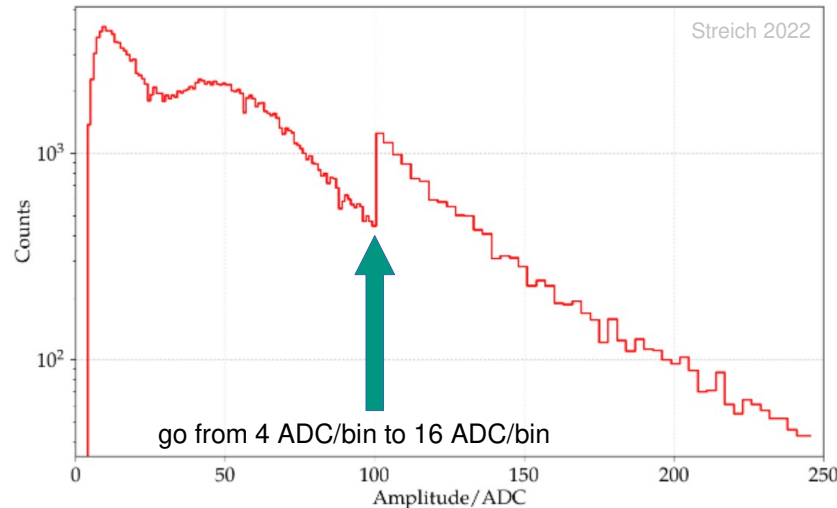
PIERRE  
AUGER  
OBSERVATORY



# Idea & terminology

## WCD offline calibration algorithm

- Fit muon hump in muon histogram



## WCD online calibration algorithm

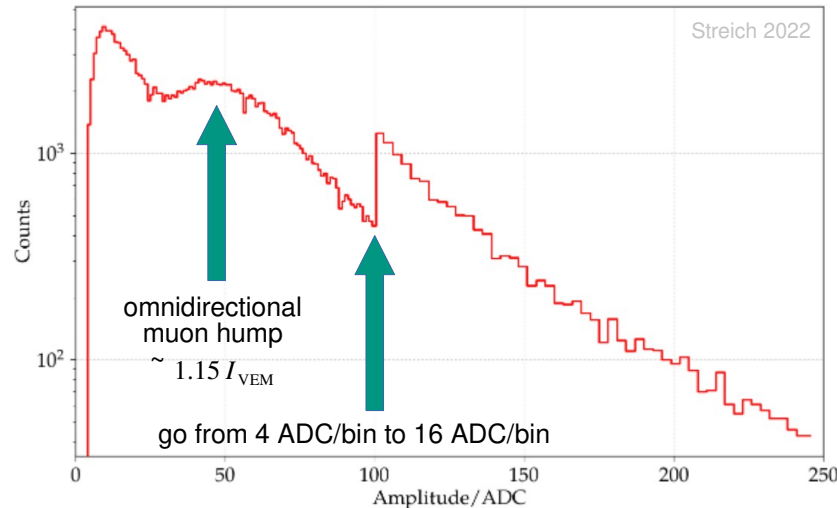
- (1) Start with a value of  $I_{\text{VEM}}^{\text{est.}} = 50$  ch.
- (2) Measure, for each PMT, the rate of events satisfying the calibration trigger by counting these events for a time  $t_{\text{cal}}$ , initially set to 5 s.
- (3) If, for a given PMT, the rate is above  $70 + \sigma$  Hz, increase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

[doi.org/10.1016/j.nima.2006.07.066](https://doi.org/10.1016/j.nima.2006.07.066)

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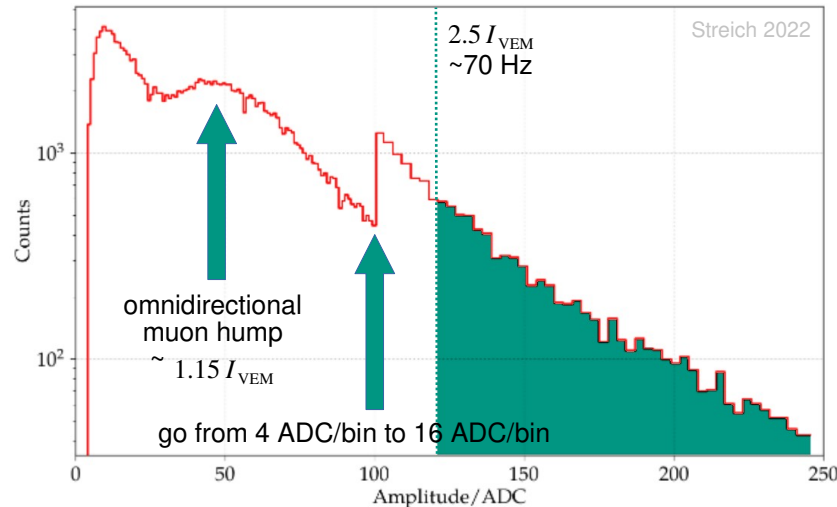
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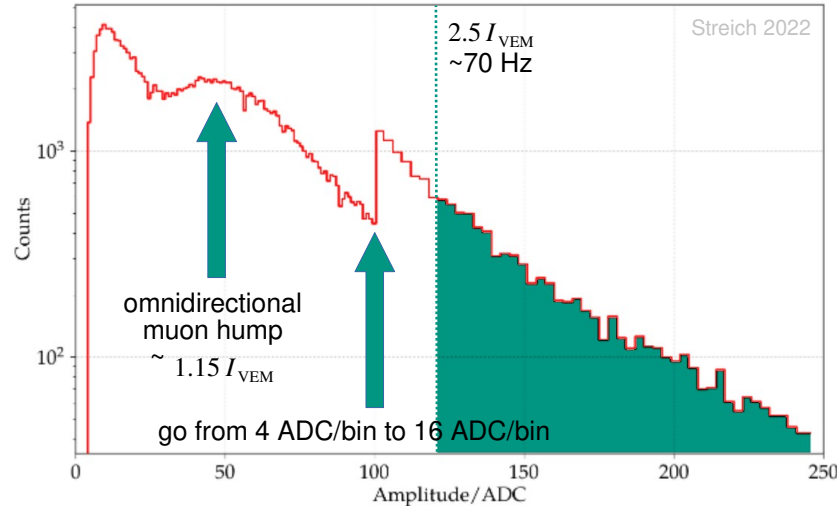
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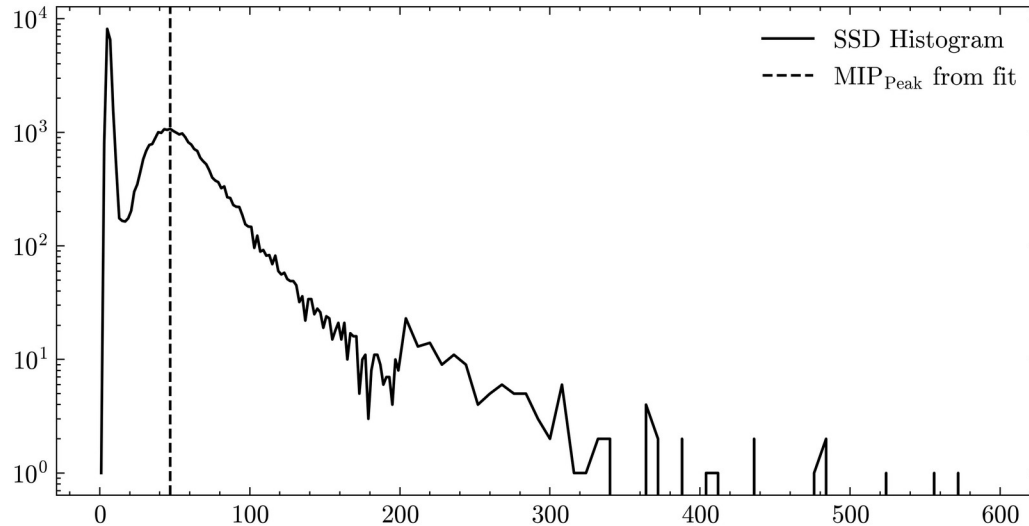
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**LACK THIS ALGO-RITHM FOR SSD!**

# 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  $I_{\text{histo}}^{\text{SSD}}$

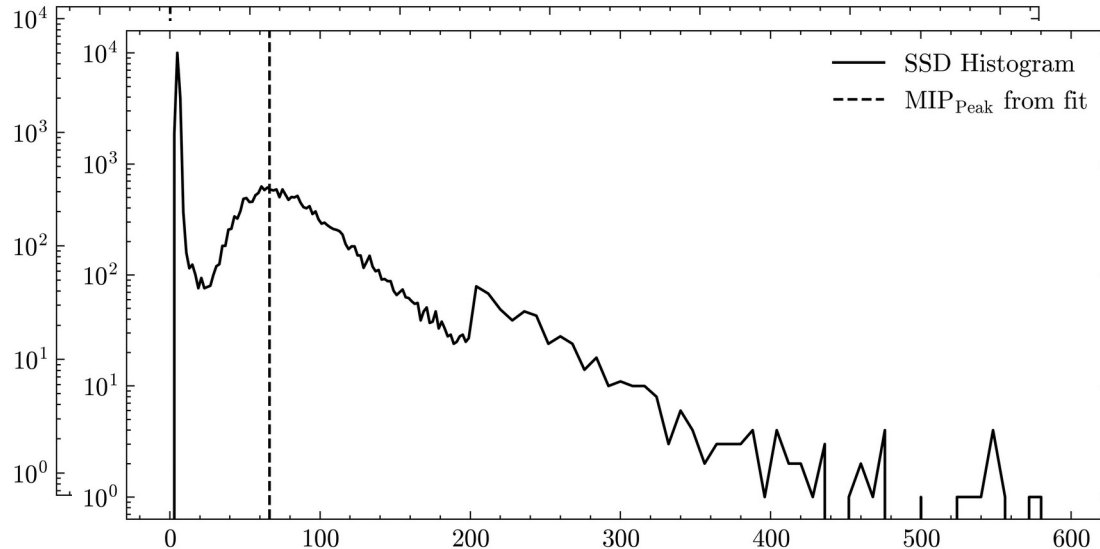


- Characteristic shape
- Scale differs due to gain
- MIP value determined by:
  - Weather
  - Electronics
  - ???
- Does there exist a stable threshold/rate relationship?



# Setting up rate/threshold relationship

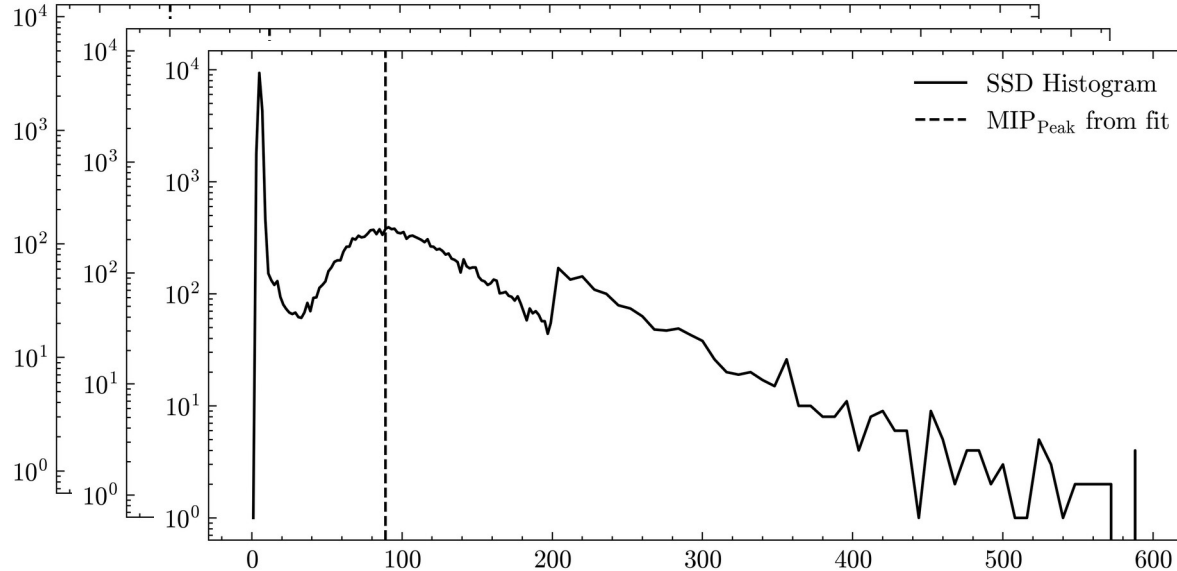
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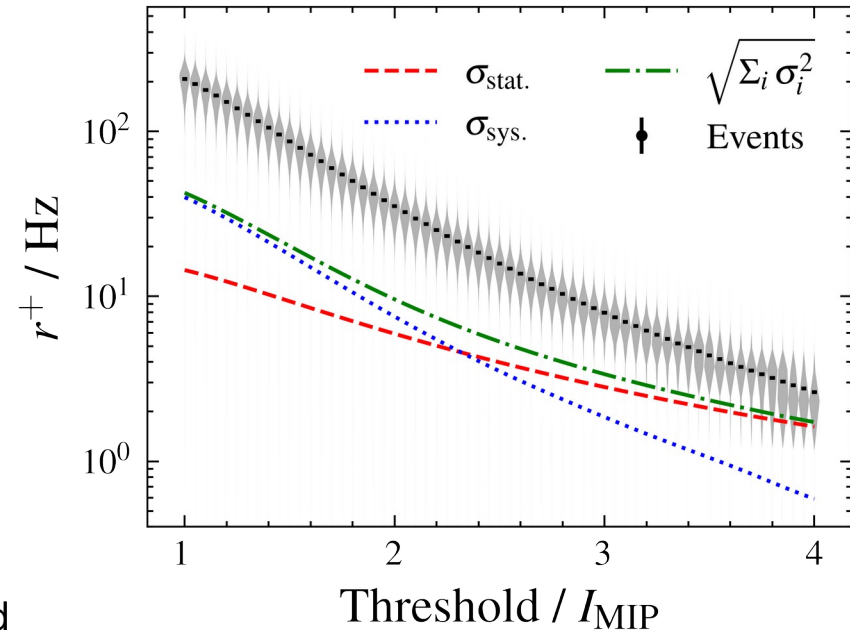


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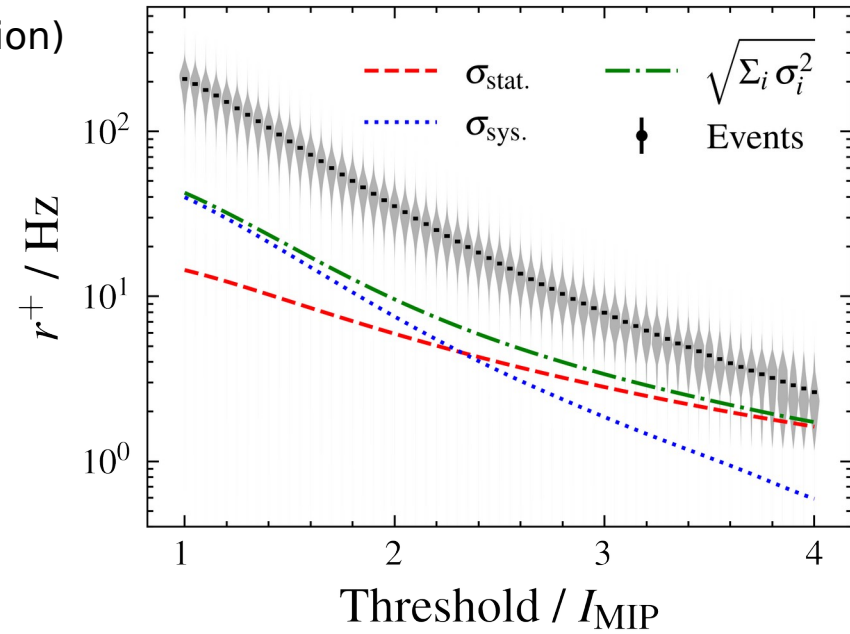
# MIP Rate

- 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  $3\sigma$
  - 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



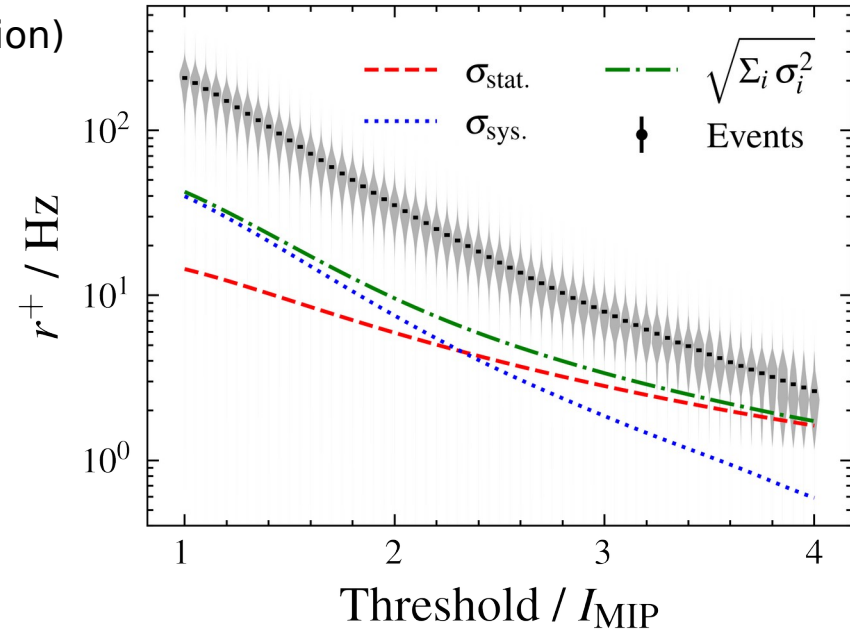
# MIP ← Rate

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



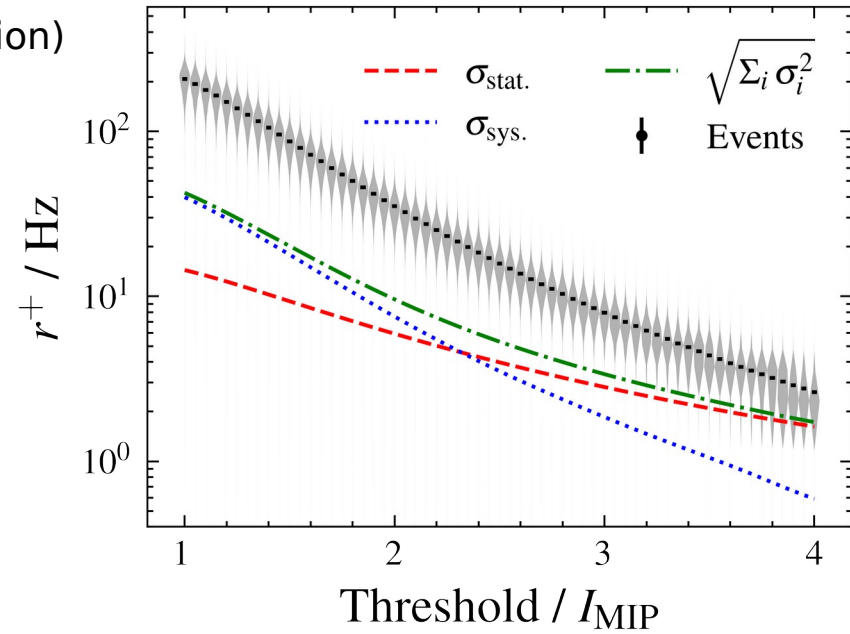
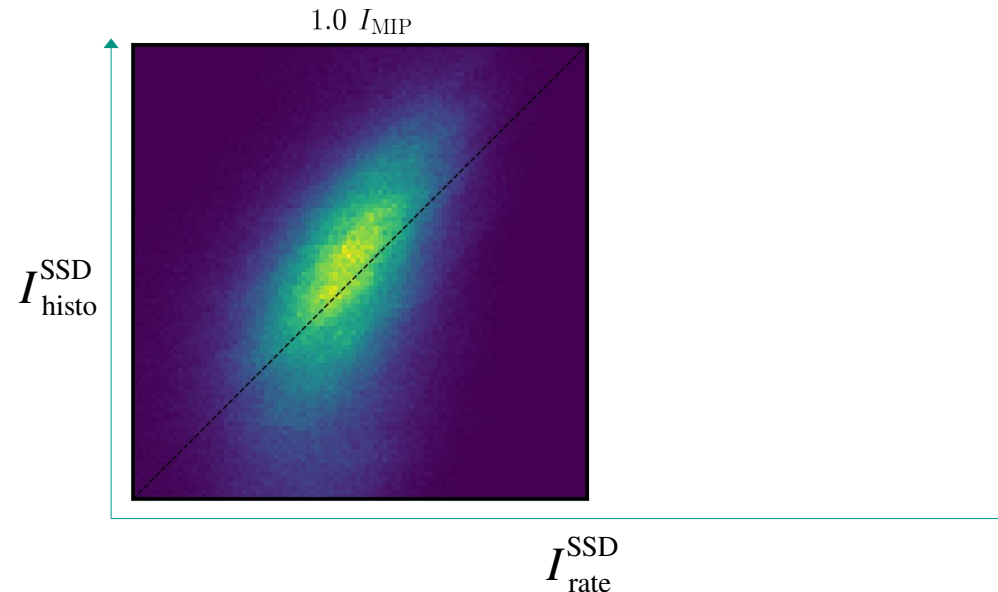
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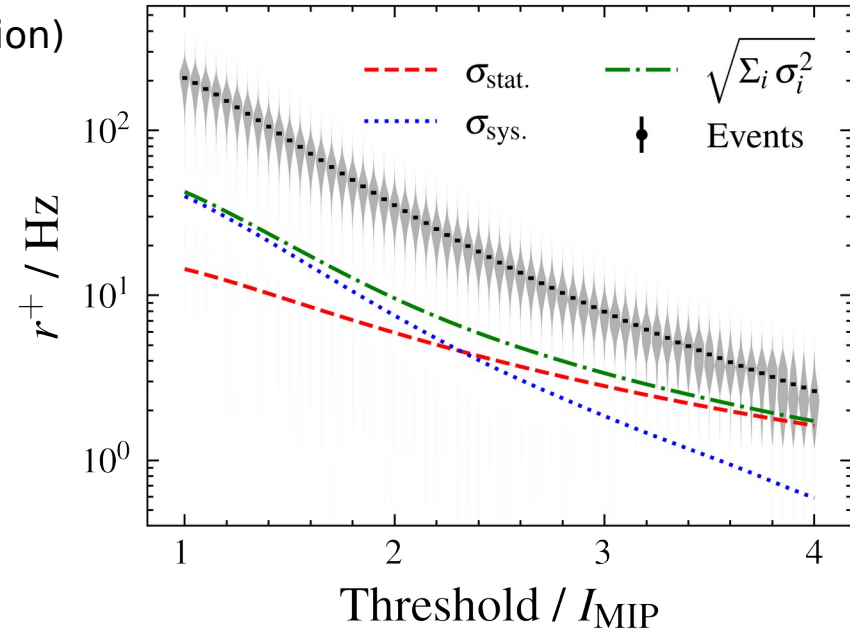
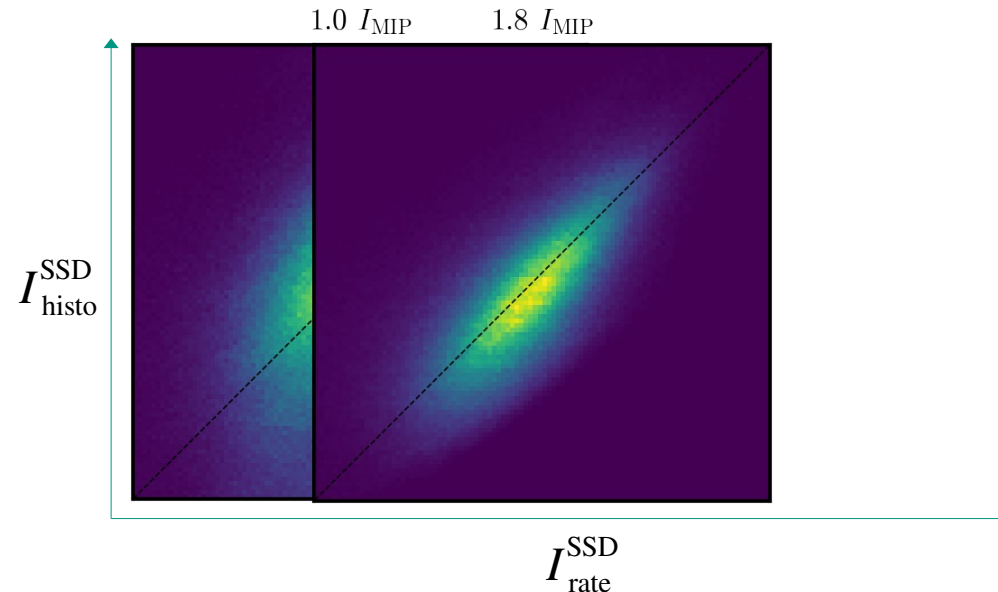
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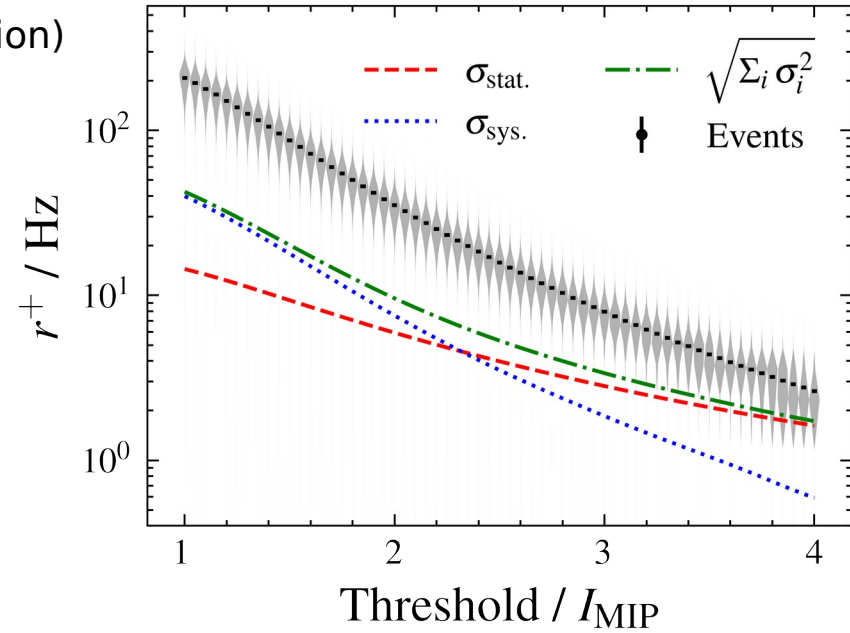
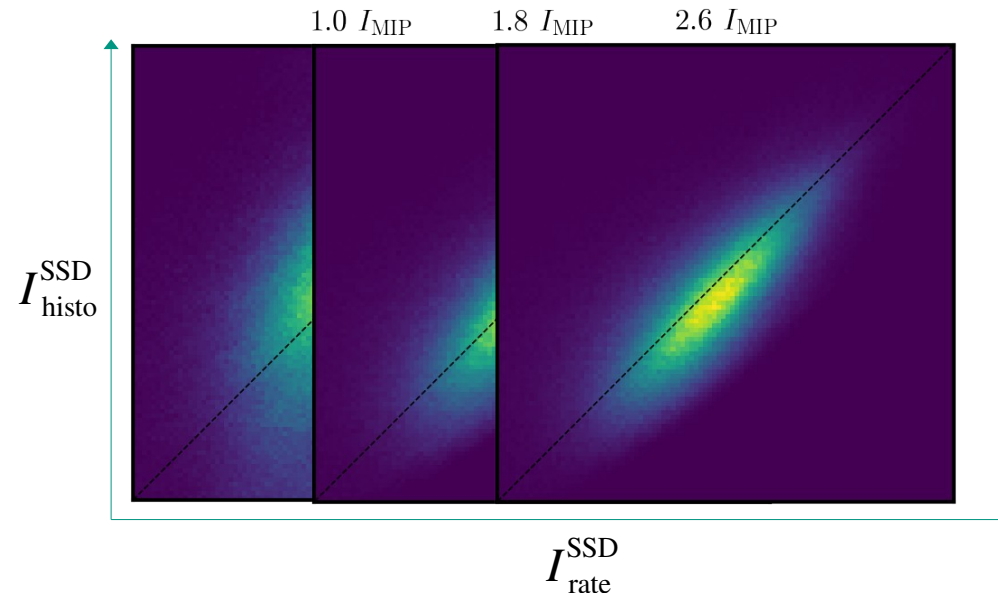
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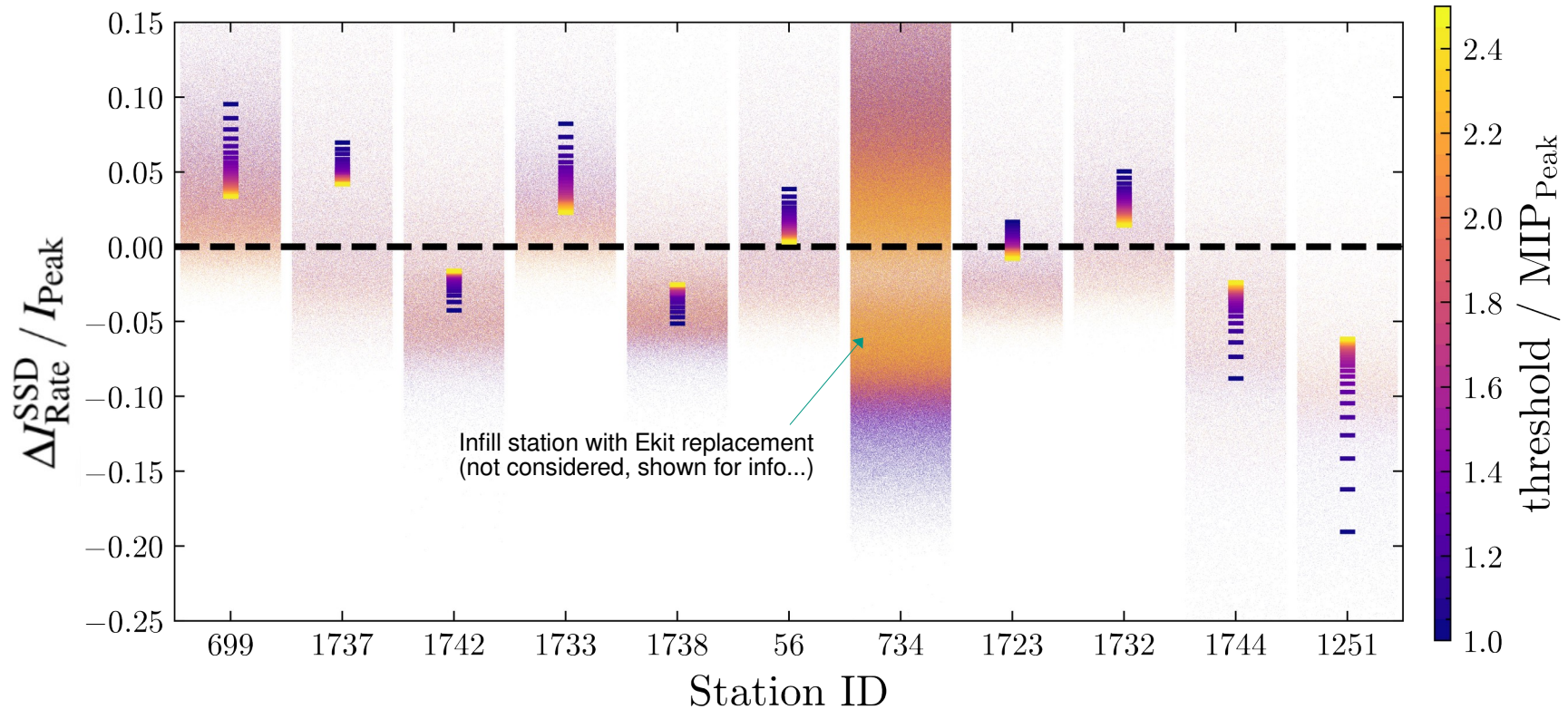


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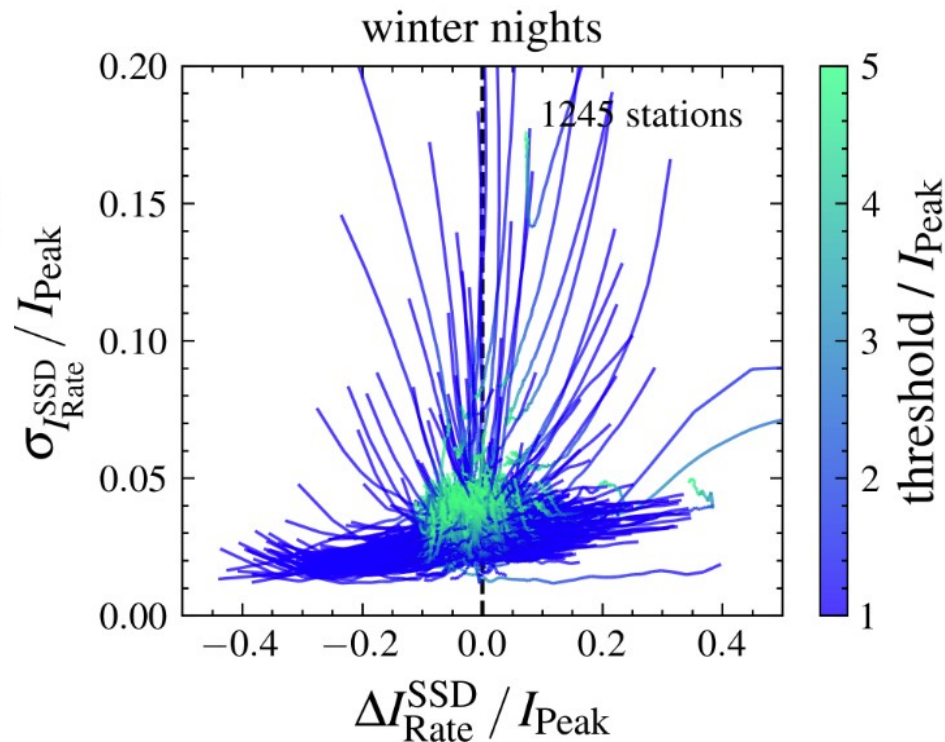
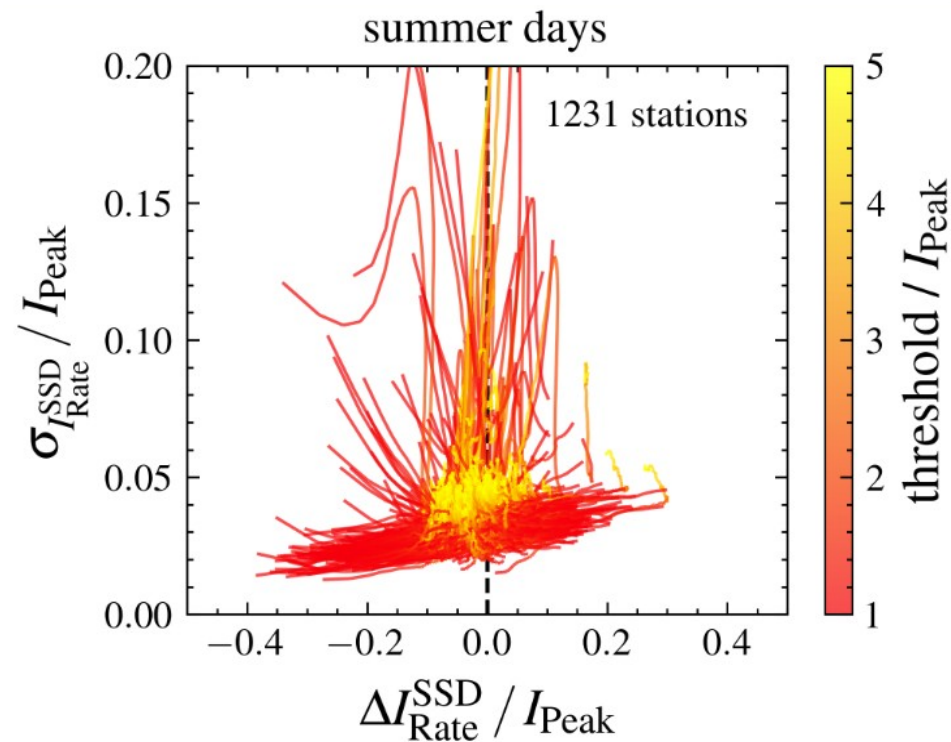


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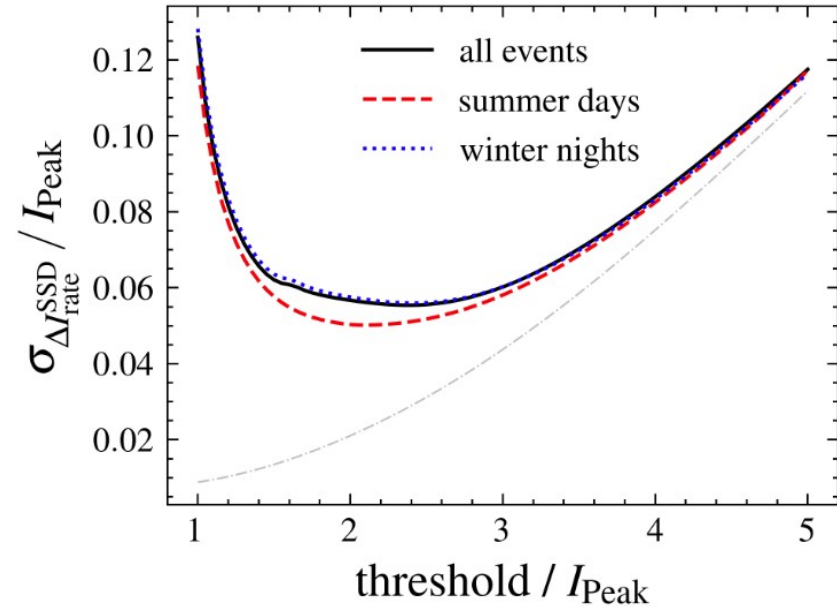
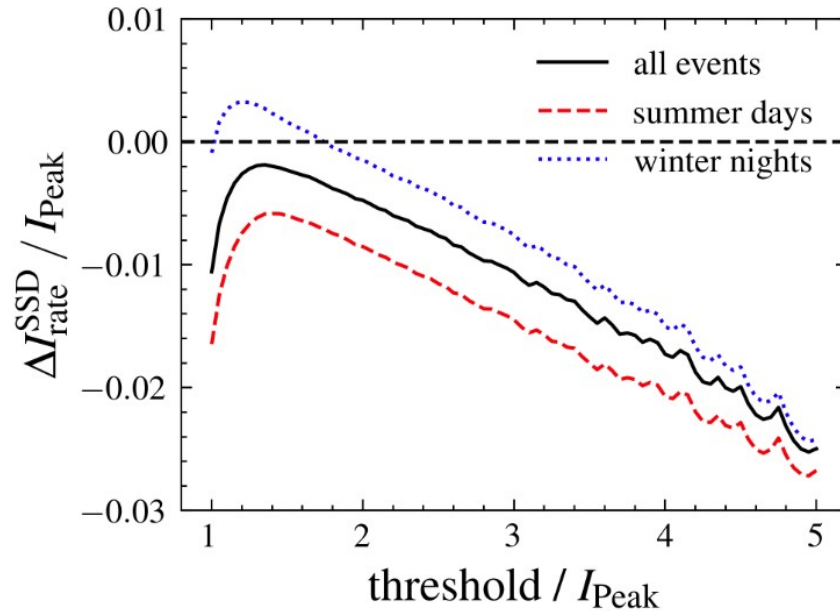




# MIP ← Rate



# 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

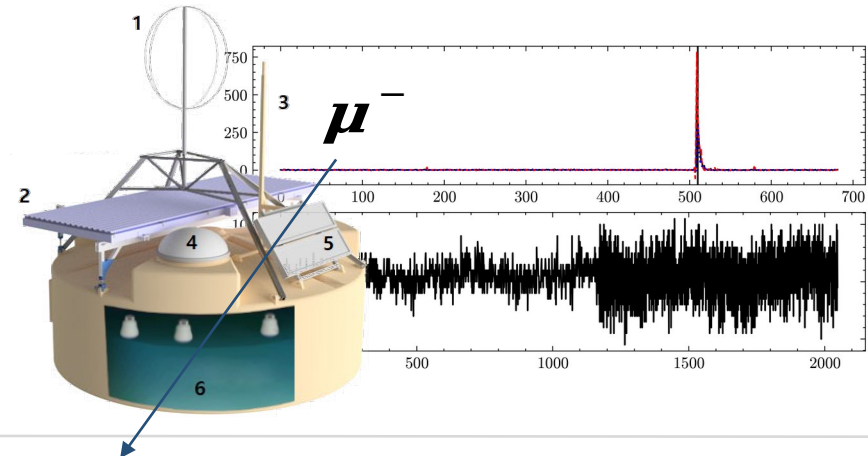
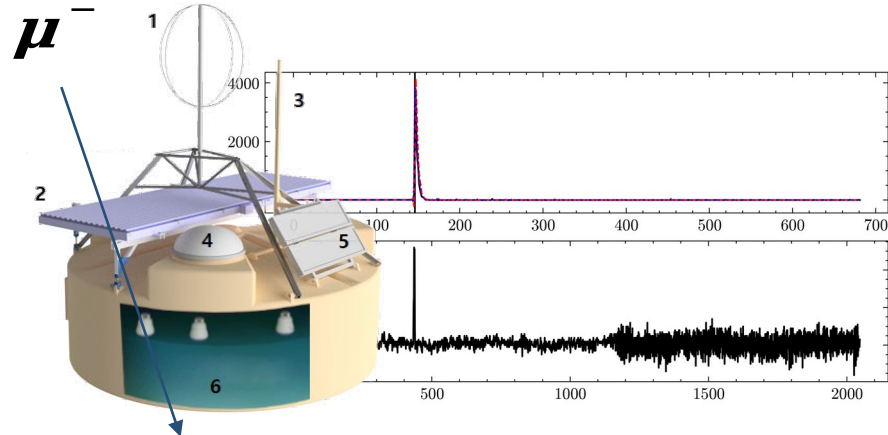
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estimate from UUB Randoms

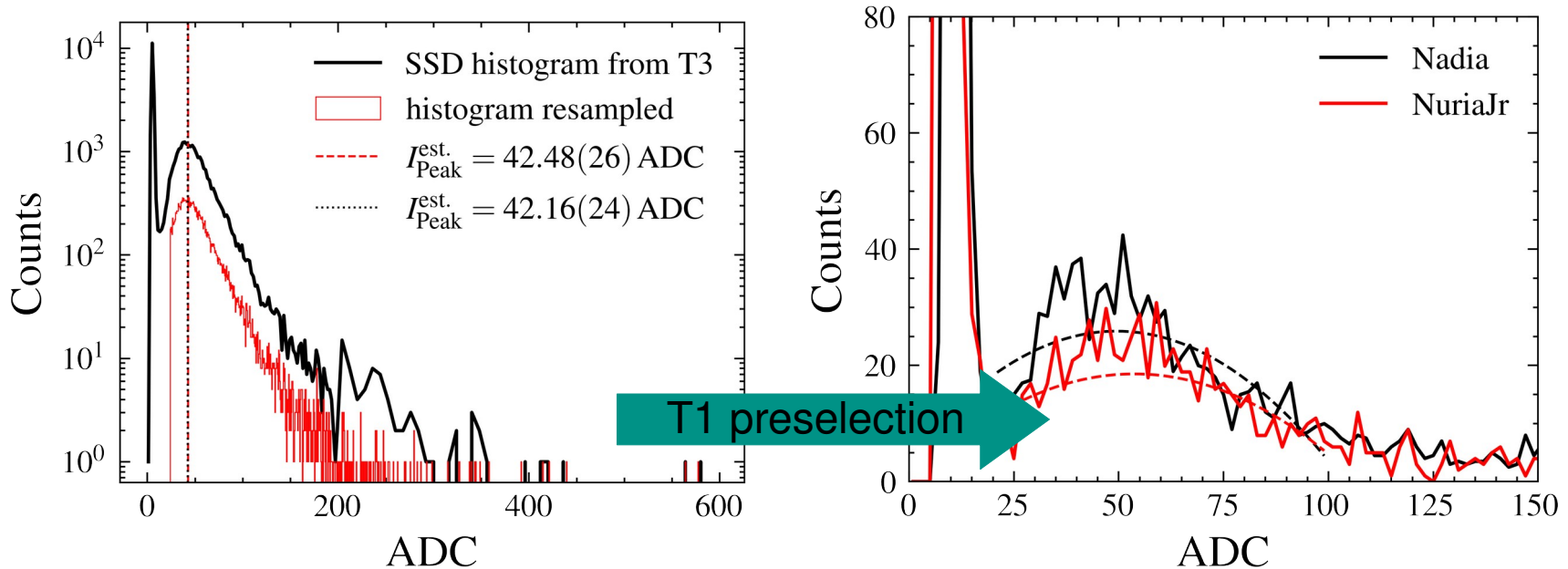
# Caveat: T1 preselection

- Build SSD pulse height histogram from events that satisfy the following:
  - Corresponding WCD traces satisfies a WCD T1 ~100 Hz
  - Coincident SSD signal with T1 latch bin ~1-2%



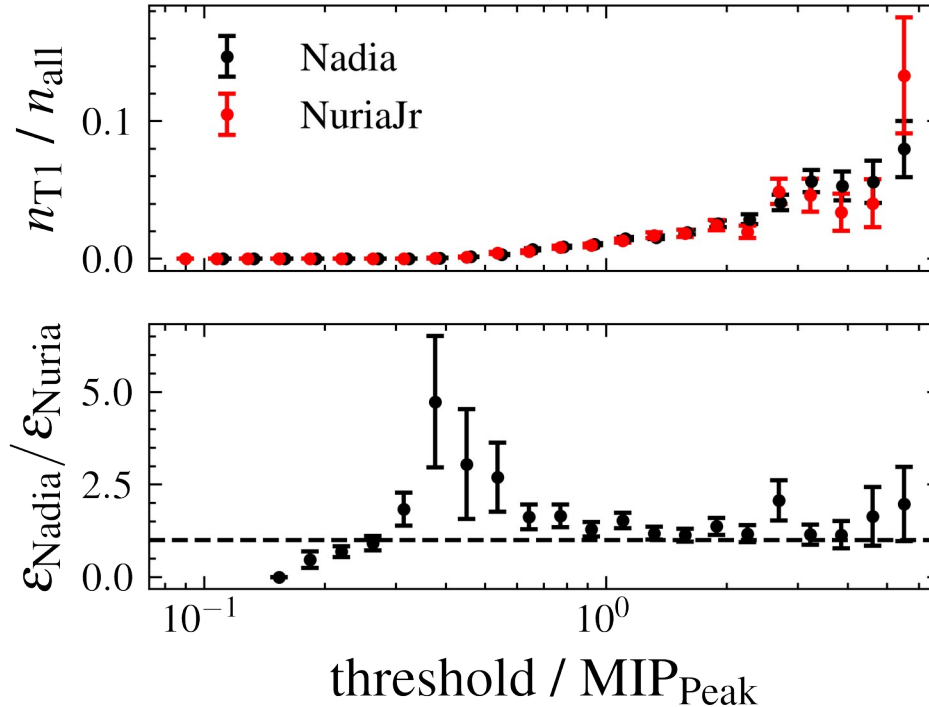
# Caveat: T1 preselection

- Rate drops by factor  $\sim 100$ , 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  $I_{\text{MIP}}$  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